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DESIGN AND OPERATING PARAMETERS FOR EMISSION CONTROL STUDIES: KENNECOTT, HAYDEN, COPPER SMELTER

I. J. WEISENBERG, ET AL

Pacific Environmental Services,
Incorporated

Prepared for:

Industrial Environmental Research
Laboratory

February 1976

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DESIGN AND OPERATING PARAMETERS FOR EMISSION CONTROL SYSTEMS: Kennecott, Hayden, Copper Smelter

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16. ABSTRACT

The report gives background design data for a specific copper smelter. The data is sufficiently detailed to allow air pollution control system engineering studies to be conducted. These studies will be concerned primarily with lean SO2 streams that currently are not being captured. Physical layout of the smelter and the surrounding area is presented, along with existing control equipment. Ductwork that would be considered for future system tie-in is defined. Emissions from operating equipment, gas flow rates, temperatures, sulfur balance, and a process flow sheet are included. Utilities, stack dimensions, footing requirements, and solid waste handling are defined. Available area for new control equipment, gas characteristic variation, and potential new control equipment installation problems are discussed.

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by

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THE FIGURES IN THIS DOCUMENT ARE NONREPRODUCIBLE

THEREFORE ARE EXCLUDED FROM THIS REPORT.

A. INTRODUCTION AND SUMMARY

The purpose of this report is to present background design data on the Kennecott Copper Corporation, Ray Mines Division smelter at Hayden, Arizona in sufficient detail to allow air pollution control system engineering studies to be conducted. These studies will be primarily concerned with lean SO_2 streams that are currently not being captured.

Physical layout of the smelter and surrounding area along with existing smelter and control equipment is presented. Ductwork that would be considered for future system tie-in is defined. Emissions from operating equipment, gas flow rates, temperatures, sulfur balance and process flow sheet are included. Utilities, stack dimensions, footing requirements, and solid waste handling are defined. Available area for new control equipment, gas characteristic variation and potential new control equipment installation problems are discussed.*

The major uncontrolled source of SO_2 at this smelter is the reverberatory furnace with approximately 8,700 tons per year of SO_2 emitted. The primary particulate emission sources are the crushing and screening operations.

B. PLANT LOCATION, ACCESS AND OVERALL GENERAL ARRANGEMENT

The Kennecott Copper Corporation smelter is located adjacent to the town of Hayden, Arizona. An enlargement of the USGS map, showing land contours of the immediate area, is presented in Figure 1. Design altitude for the plant is 2200 ft. with latitude 33° 00' and longitude 110° 47'. The plant layout is shown in Figure 2. The smelter general arrangement is shown in Figure 3. As seen in the general arrangement drawing, the smelter layout is relatively compact, with most available space east of the main stack and smelter building.

---

*The information contained herein was obtained from a smelter visit in 1974 and from the State of Arizona. Kennecott/Hayden has taken the position that they do not need additional control equipment and do not feel obligated to supply the additional detailed information required to complete this report.

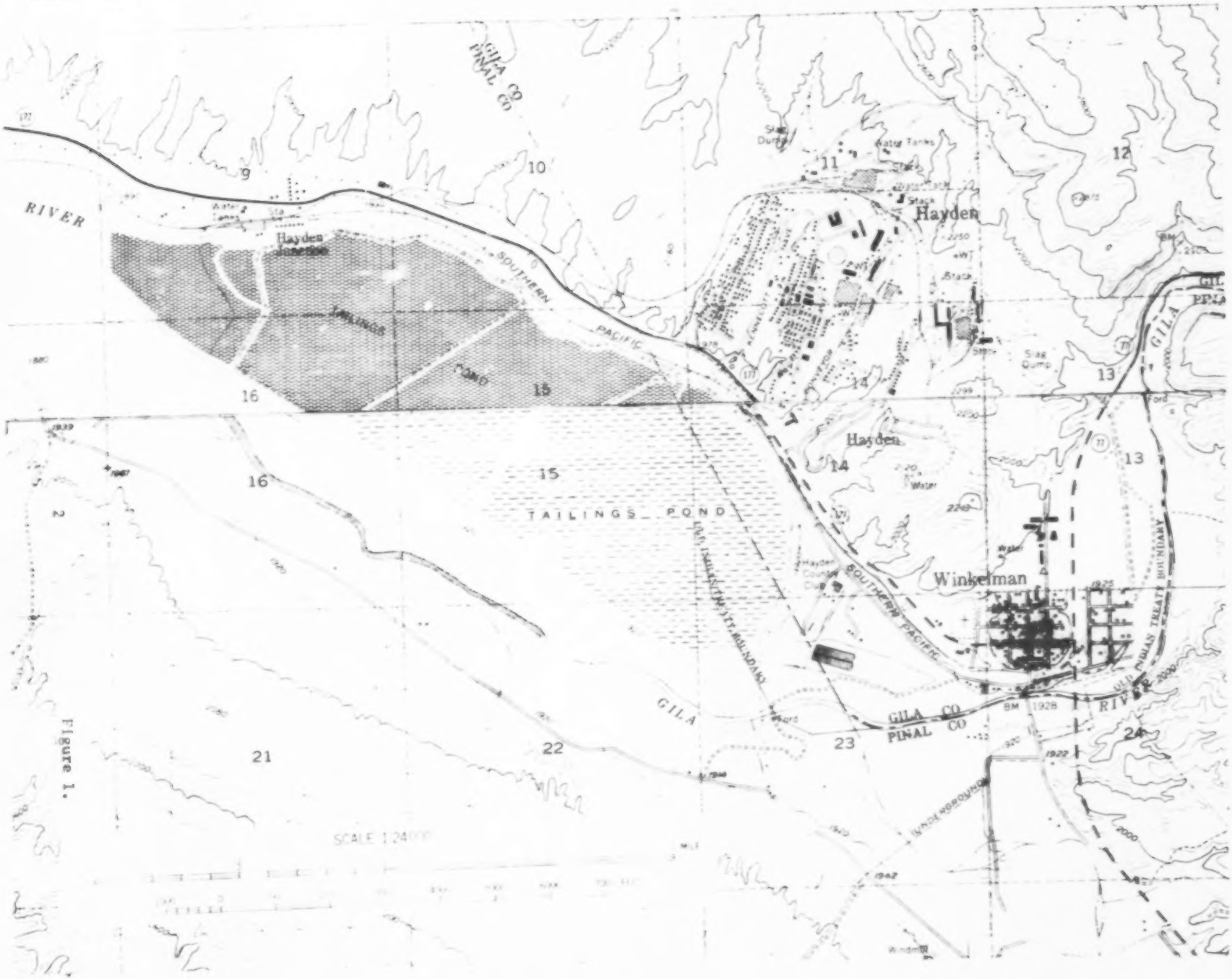
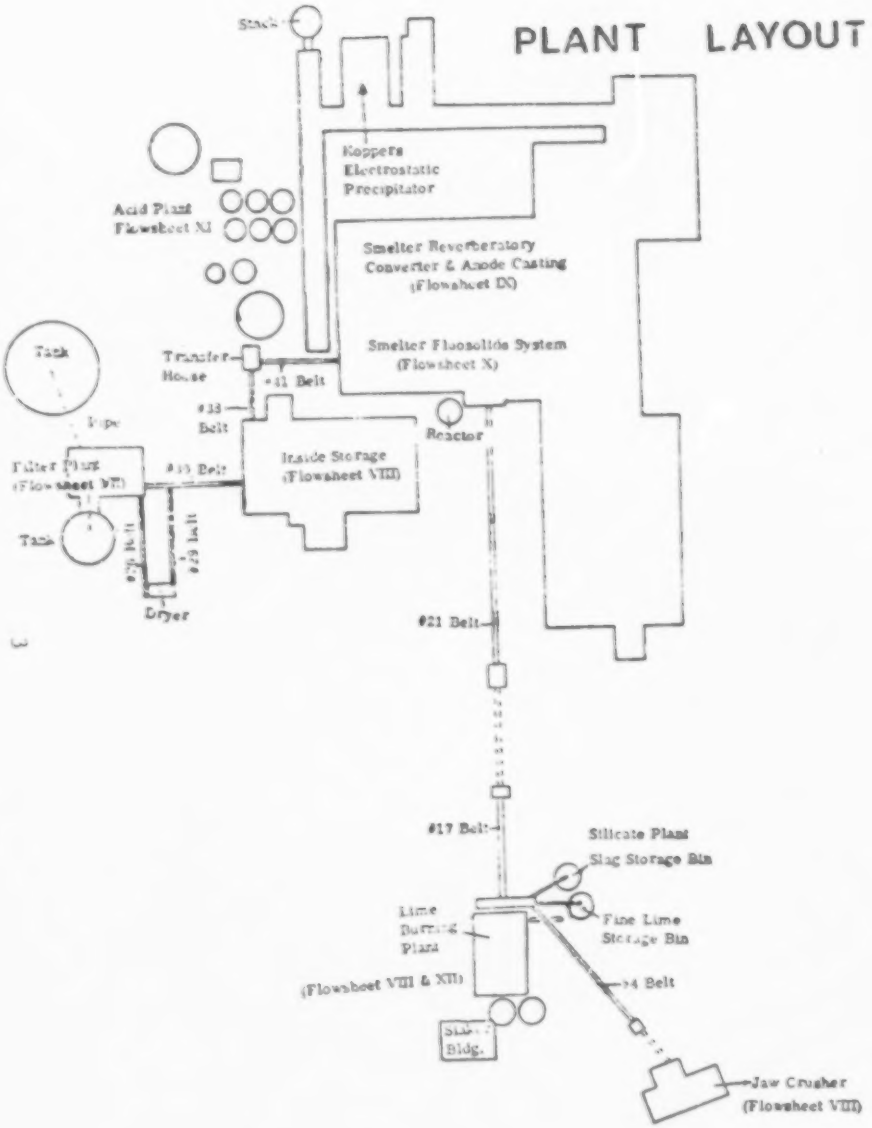

GILA
PINAL CO
RIVER
Hayden Junction
TAILINGS POND
SOUTHERN PACIFIC
Hayden
Winkelman
GILA CO
PINAL CO
GILA
SCALE 1:24000

Figure 1.

PLANT LAYOUT AND FLOWSHEET REFERENCE



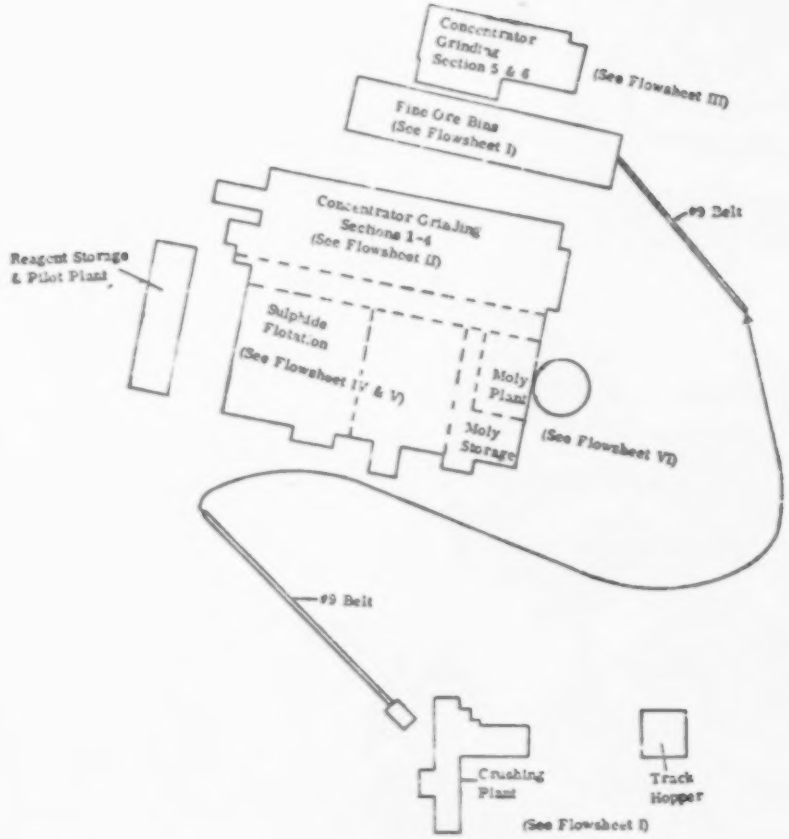


Figure 2

Figure 3. OVERALL PLANT AND GENERAL ARRANGEMENT
(Located in Pocket Inside Back Cover)

The smelter portion of the plant consists of the initial ore handling, crushing, grinding and mixing equipment, a fluo-solids reactor, a reverberatory furnace with two waste heat boilers, three converters, an anode furnace and anode casting wheel. Five vertical lime kilns are also used.

The pollution control equipment consists of cyclones and rotoclones for the crushing, grinding, screening and materials handling operations and lime kilns. Reverberatory furnace gases pass through two waste heat boilers, a balloon flue and a four chamber electrostatic precipitator before exiting through a 600 foot stack. Fluo-solids reactor offgases pass through primary and secondary cyclones and a gas cooler before entering the acid plant system. Converter offgases are cooled and then pass through a two chamber electrostatic precipitator before entering the acid plant system. In the acid plant, fluo-solids reactor and converter gases are treated in separate scrubbers, combined, and passed through three parallel trains of two mist precipitators in series, a drying tower, a mist eliminator, and into a double contact acid plant. Acid plant tail gases are vented to a 100 foot stack.

C. PROCESS DESCRIPTION

The Kennecott Copper Corporation Smelter at Hayden was put on stream in mid-1958 as a green-feed sidewall-charged reverberatory furnace with Peirce-Smith converters. All gases, after dust removal in electrostatic precipitators, were discharged through a 600-ft. stack. In 1966 it was decided to convert the plant to a calcine reverberatory using a fluo-solids roaster. Roaster gases were to be cleaned and sent to a 750-ton per day acid plant. The design was started in June 1967, and construction completed March 1969. The basis for the decision was to provide a source of acid for mine leaching, increase capacity of the green-feed reverberatory furnace, and reduce air pollution.

Concentrate, silica sand, lime flux, and precipitate copper

in the following proportions are blended together prior to being fed into the fluo-solids reactor. (Ref. 1).

Concentrate	88.68 %
Lime Flux	3.93 %
Silica Flux	3.93 %
Precipitate	3.46 %
	100.00 %

The process weight varies from 1200 to 1400 TPD. The blended material contains from 6 to 12 percent moisture and is fed into the reactor through a screw feeder. This feeder both controls the feed rate and seals the reactor vessel. Fluidizing air at approximately 3 psi is supplied to the reactor tuyeres in the floor of the reactor. The bed which is about 4 feet deep is in a constant fluidized state. The sulfide ore reacts with the fluidizing air and partially oxidizes forming SO_2 gas and calcine. Operating temperatures range from 1,000 to 1,150°F. The process is controlled by limiting the air volume (O_2). Approximately 50 percent of the total sulfur is converted to SO_2. The reaction is exothermic and therefore natural gas is not required except for cold startup. Gas and fine solids leave the reactor by duct and pass through primary and secondary cyclones. The calcine is collected and fed to the reverberatory furnace via calcine bin and Wagstaff feeder. The oversize material in the reactor is withdrawn by a cone type valve located in the reactor floor and is conveyed by drag chain to the calcine bin. The gas from the cyclones is cooled in the gas cooler (1,000°F to 800°F.) The reactor gas is then combined with the converter gas and is fed to the acid plant.

Calcine and precipitator dust are smelted in the reverberatory furnace. Slag is skimmed from the bath and removed by slag train to a dump. Copper matte is tapped near the bottom of the bath and transferred by ladle to the converters.

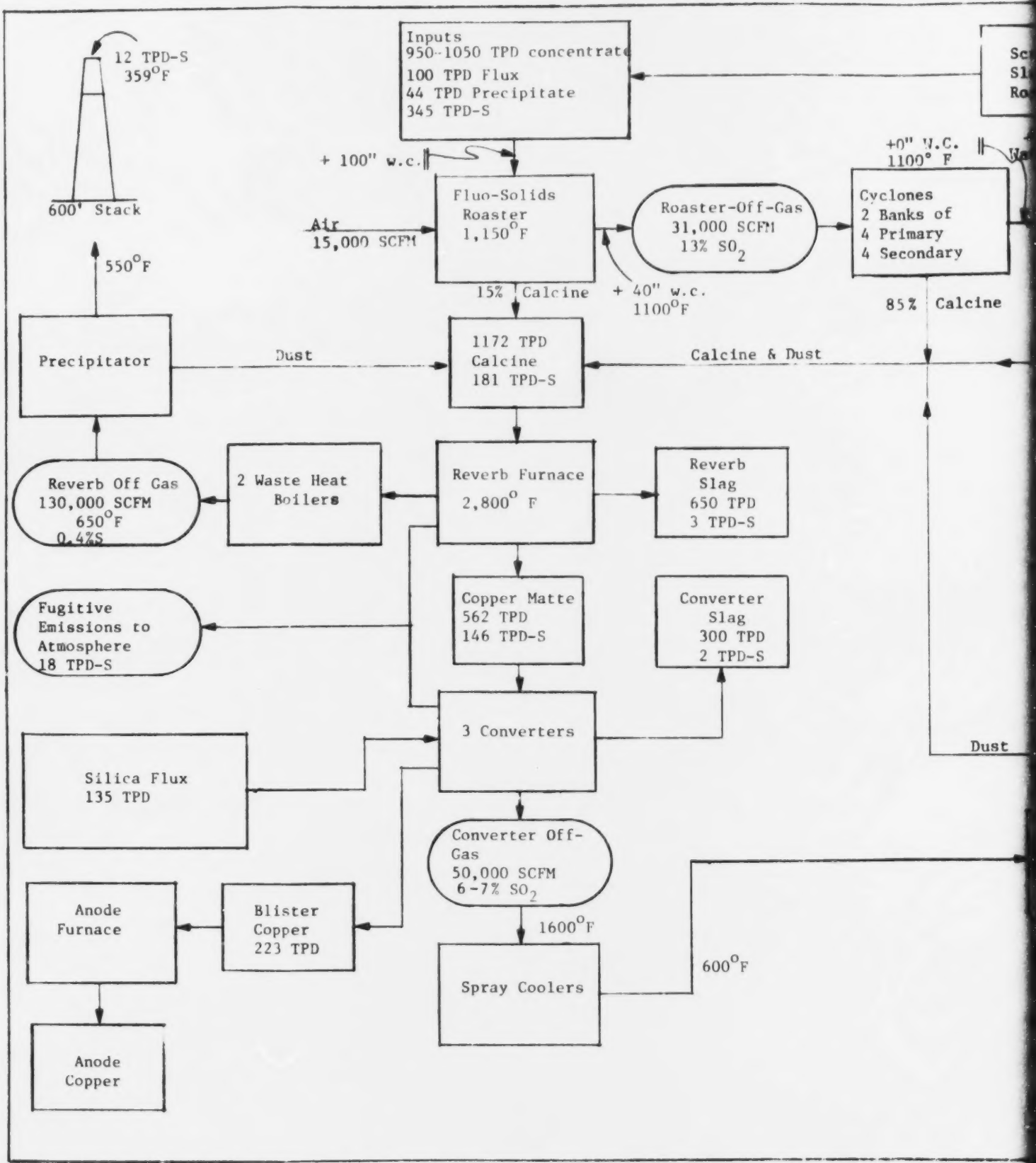
Combustion air for the reverberatory furnace is supplied at 700°F by a Lungstrom preheater. Both the preheater and reverberatory furnace are natural gas fired. In addition, the reverberatory furnace is equipped with diesel oil burners for stand-by service. Combustion gases from the furnace pass through the uptakes into two waste heat boilers. The gases then enter the reverberatory furnace balloon flue and travel to an electrostatic precipitator and then to the smelter stack. The dust collected is returned by screw conveyors to the calcine bins. The dust loading in the smelter stack averages 0.04 grains per SCF. The gas flow rate at the stack exit is approximately 130,000 SCFM and the average stack gas temperature is 360°F.

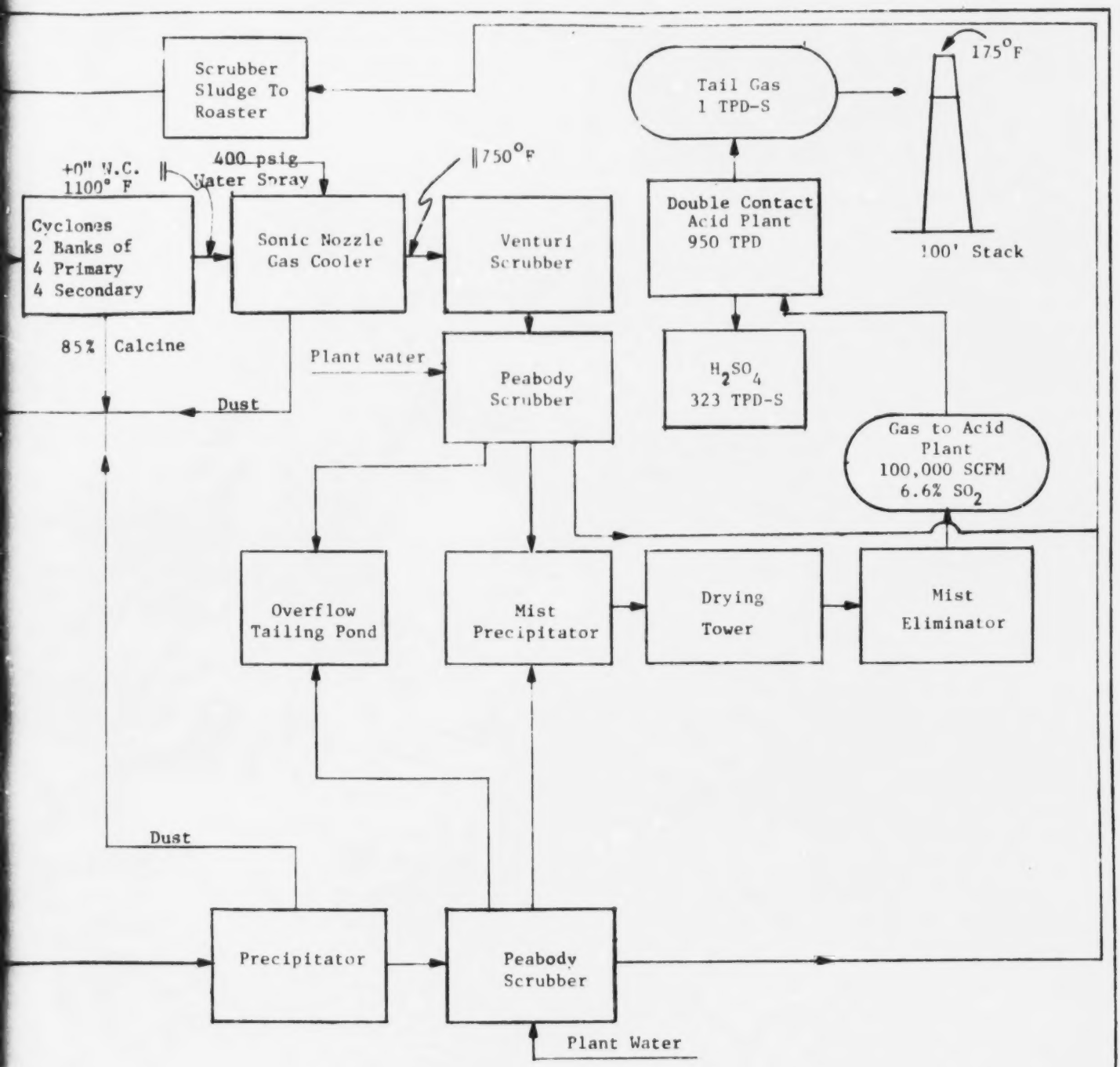
The process flow diagram with sulfur balance and typical gas temperature and flow data is shown in Figure 4.

A set of process flow sheets prepared by Kennecott Copper Corporation (Ref. 2) are reproduced in Appendix A for reference.

a. Fluo-solids Reactor

The fluo-solids reactor system is illustrated in Figure 5. The system was designed by Dorr-Oliver in conjunction with Kennecott engineering (Ref. 2). The original system included a preheater for the fluidizing air, a fluo-solids roaster or reactor, dual flues to banks of four primary and four secondary cyclones each equipped with jug dampers, and calcine bins and feeders. Air preheater failures led Kennecott to by-pass the preheater. Preheated air has not been used for the past few years. To assist in starting the reactor Kennecott now uses about a ton of 3/4 inch slack coal mixed with sand and fired by two auxiliary burners through the sidewall. The reactor is 13 feet 6 inches in diameter with 373 tuyeres. Fluidizing air at approximately + 100 inch w.c. (water column) is supplied to the reactor


12 TPD-S
359°F
600' Stack
Inputs
950-1050 TPD concentrate
100 TPD Flux
44 TPD Precipitate
345 TPD-S
+ 100" w.c.
Air
15,000 SCFM
Fluo-Solids
Roaster
1,150°F
Roaster-Off-Gas
31,000 SCFM
13% SO2
+0" W.C.
1100° F
Cyclones
2 Banks of
4 Primary
4 Secondary
550°F
15% Calcine
+ 40" w.c.
1100°F
85% Calcine
Precipitator
Dust
1172 TPD
Calcine
181 TPD-S
Calcine & Dust
Reverb Off Gas
130,000 SCFM
650°F
0.4%S
2 Waste Heat
Boilers
Reverb Furnace
2,800° F
Reverb
Slag
650 TPD
3 TPD-S
Fugitive
Emissions to
Atmosphere
18 TPD-S
Copper Matte
562 TPD
146 TPD-S
Converter
Slag
300 TPD
2 TPD-S
3 Converters
Dust
Silica Flux
135 TPD
Converter Off-
Gas
50,000 SCFM
6-7% SO2
Anode
Furnace
Blister
Copper
223 TPD
1600°F
Spray Coolers
600°F
Anode
Copper



PROCESS FLOW & SULFUR BALANCE

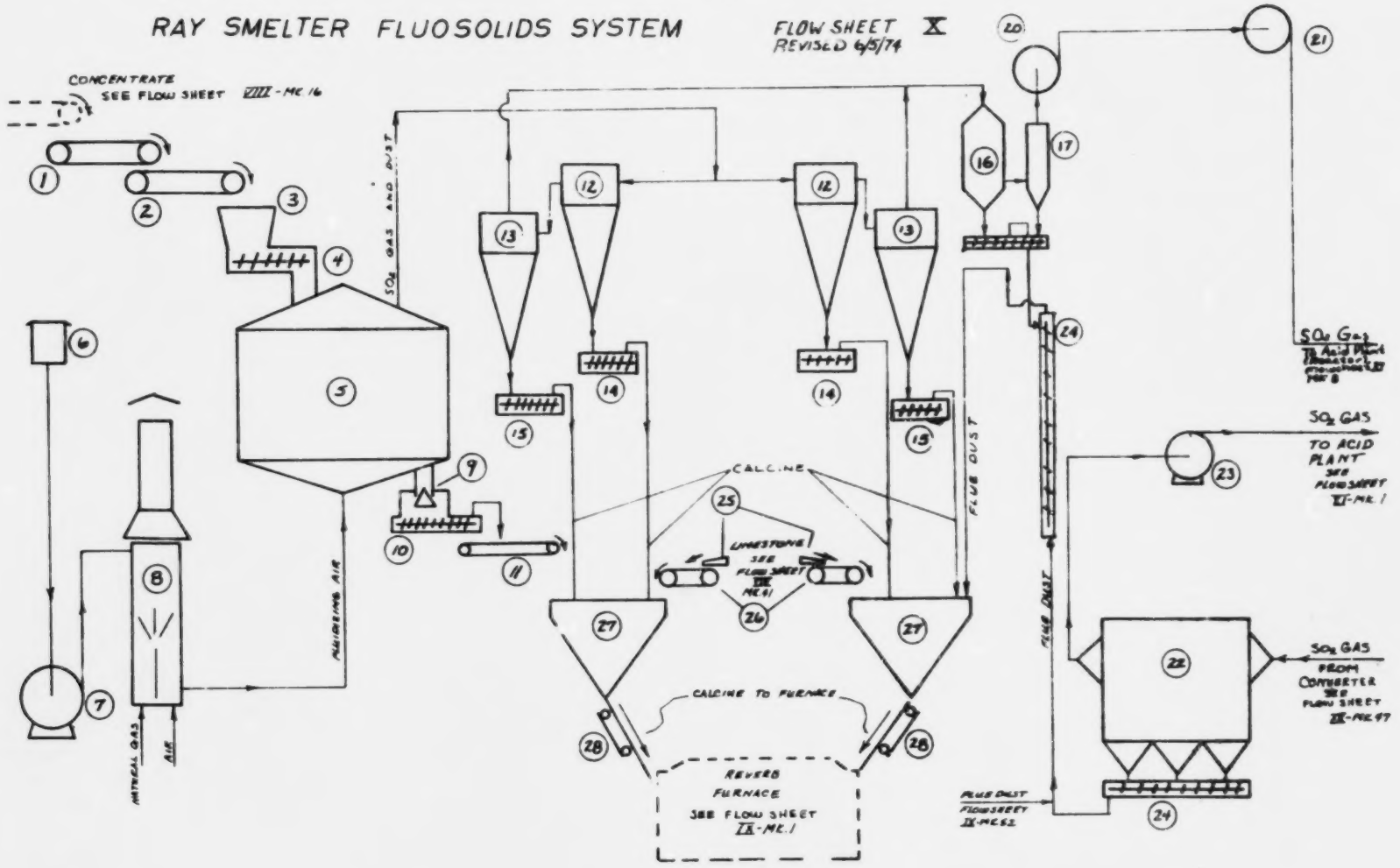
Kennecott Copper Co./Hayden Branch | prepared August, 1975

PACIFIC ENVIRONMENTAL SERVICES

Figure 4.

RAY SMELTER FLUOSOLIDS SYSTEM

FLOW SHEET X
REVISED 6/5/74



MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION
1	1	24" Conveyor Belt	9	1	Airflow	17	1	Gas Boiler Upleg	25	2	Vibratory Feeders
2	1	24" Conveyor Belt	10	1	Airflow Seal Screw	18		Deleted	26	2	Welsh Belt Conveyor
3	1	Concentrate Feed Hopper	11	2	Drag Chain Conveyor	19	10	Screw Conveyors	27	2	Calcine Feed Bin
4	1	Concentrate Screw Feeder	12	4	Primary Cyclone	20	2	Reactor ID Fan Intermediate	28	2	Jeffstaff Feeder
5	1	Fluosolids Reactor	13	4	Secondary Cyclone	21	1	Reactor ID Fan West			
6	1	Air Filter	14	2	Primary Cyclone Seal Screw	22	1	Converter Gas Electrostatic Precipitator			
7	1	Fluidizing Air Blower	15	2	Secondary Cyclone Seal Screws	23	1	Converter Gas ID Fan			
8	1	Preheater	16	1	Gas Boiler	24	13	Screw Conveyors			

Figure 5

through a distribution plate in the floor of the reactor. The distribution plate contains 373 spuds each containing seven 1/4 inch diameter holes (Ref. 3). A pressure drop of approximately 60 inches w.c. is experienced in the reactor. Downstream of the cyclones the pressure is 0 inches w.c. and remains below atmospheric pressure throughout the remainder of the duct system to the acid plant. Approximately 25,000 SCFM of roaster gas is treated at the acid plant. The roaster gas feed ports must be cleaned out once a month. This operation requires 14 hours and is accomplished by going into the roaster and drilling out the over 2000 holes.

The bed, in a constant fluidized state, is about 4 feet deep. The sulfide ore reacts with the fluidizing air and partially oxidizes forming SO_2 gas and calcines. About 50 percent of the total sulfur is converted to SO_2 in the reactor. The process is controlled by limiting the air volume (O_2). The operating temperature ranges from 1000 to 1150°F. No fuel is required except for cold startup because the reaction is exothermic. Approximately 15% of the roasted material (calcine) is removed as "underflow" along two sides of the distribution plate. The rest of the roasted material leaves in the gas stream and is recovered in the cyclones.

b. Reverberatory Furnace

A flowsheet showing the equipment and process steps associated with the reverberatory furnace, converters, and anode casting operations appears as Figure 6. Calcines, approximately 1100 to 1200 TPD, are fed into the reverberatory furnace through a pair of Wagstaff feeders. The reverberatory furnace, a suspended arch design, 30 feet wide by 100 feet long, generates 120,000 to 130,000 SCFM of offgas with an average sulfur dioxide concentration of about 0.5%.

The reverberatory furnace is natural gas fired and has a natural gas fired Lungstrom air preheater. Approximately 202,527 MSCF of natural gas is burned monthly in the furnace and 16,490 MSCF

is burned monthly in the preheater (Ref. 1). Gases from the furnace pass through the reverberatory uptake and through a pair of waste heat boilers. Dust collected in hoppers beneath the waste heat boilers is carried by a front-end loader to the converters.

The reverberatory furnace operates at a slight negative pressure, -0.06 inches w.c. It is fed intermittently by dropping calcines through the Wagstaff feeders. Feeding takes place two minutes in every fifteen minutes. The furnace operates at about 0.6% CO. This is possible because a major portion of the sulfur is removed in the fluo-solids roaster.

Slag is removed at an average rate of 650 TPD and transported to a slag dump in slag cars. The reverberatory slag contains approximately 0.2 to 7.5 TPD of sulfur.

Approximately 25 to 30 ladles of matte per day are handled from the reverberatory furnace. It generally takes 10 to 20 minutes to fill a ladle. During matte tapping there is evidence of considerable fuming and SO_2. Kennecott is planning to enclose the matte tap. The matte is taken by car to the converters at a typical rate of 562 TPD.

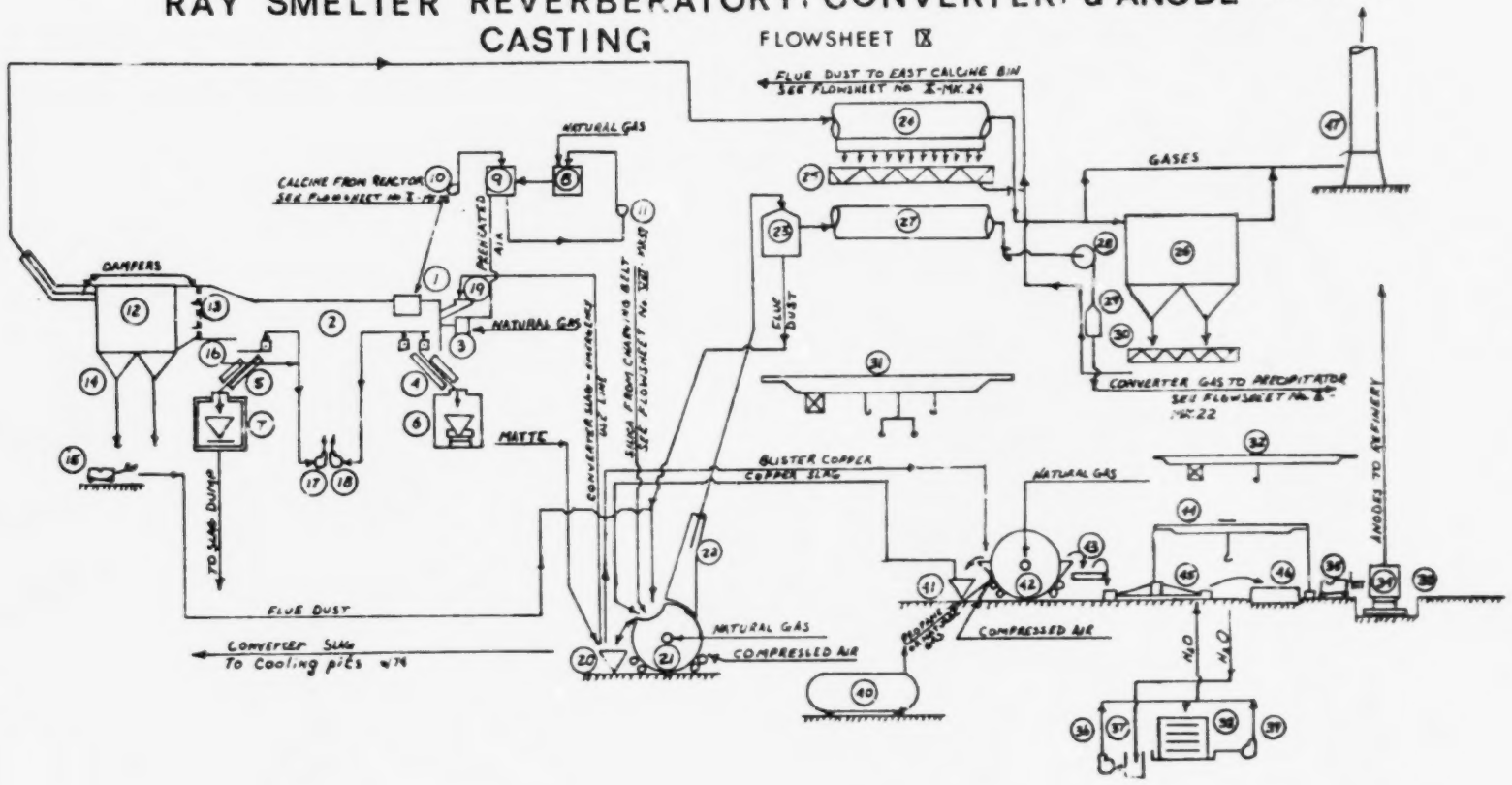
c. Converters

The equipment associated with operation of the converters is designated on the process flow sheet, Figure 6. Eight 200 cubic foot ladles feed the converters. There are presently three Peirce-Smith converters, 13 feet in diameter by 30 feet long equipped with forty-two 2 inch tuyeres. The converter aisle is served by two P & H cranes each with a 60-ton main hoist and two 20-ton auxiliary hoists. The converters are natural gas fired and typically process 135 TPD of silica flux and 526 TPD of copper matte. At this charge rate, 223 TPD of blister copper is produced and sent to two anode furnaces and then to a casting wheel. Typically, 300 TPD of converter slag containing an average of 3 to 5 TPD of sulfur is generated.

RAY SMELTER REVERBERATORY, CONVERTER, & ANODE CASTING

FLOWSHEET IX

REVISED 6/14/74



NO.	NO.	DESCRIPTION	NO.	NO.	DESCRIPTION	NO.	NO.	DESCRIPTION	NO.	NO.	DESCRIPTION	NO.	NO.	DESCRIPTION
1	2	Waste Heat Boilers	23	1	Converter Gas Cooler	34		Railroad Box Car	45	1	Anode Casting Wheel			
2	1	Reverberatory Furnace	24	1	Reverberatory Uptake	35	4	Fork Lift Truck	46	2	Bosh Tank			
3	3	Burners	25	3	Dust Collecting Hoppers	36	1	Pump Sump	47	1	500' High Stack			
4	2	Matte Launder	26	1	Electrostatic Precipitator	37	3	Anode Cooling Water Pumps						
5	2	Slag Launder	27	3	High Velocity Flues	38	1	Anode Cooling Water Tower						
6	2	Matte Transfer Cars	28	1	Converter ID Fan	39	3	Anode Cooling Recirculating Pumps						
7	4	Slag Cars	29	1	Dust Hopper	40		Propane Storage						
8	1	Preheater Furnace	30	1	Precipitator Screw Conveyor	41		200 Cu. Ft. Ladle						
9	1	Reverberatory Air Preheater	31	2	100 Ton Converter Aisle Crane	42	2	Anode Furnace						
10	1	Forced Draft Fan	32	1	Casting Crane	43	2	Anode Wheel Pouring Spoon						
11	1	Recirculating Air Fan	33	1	Truck Scale	44	1	Bosh Crane						

Figure 6

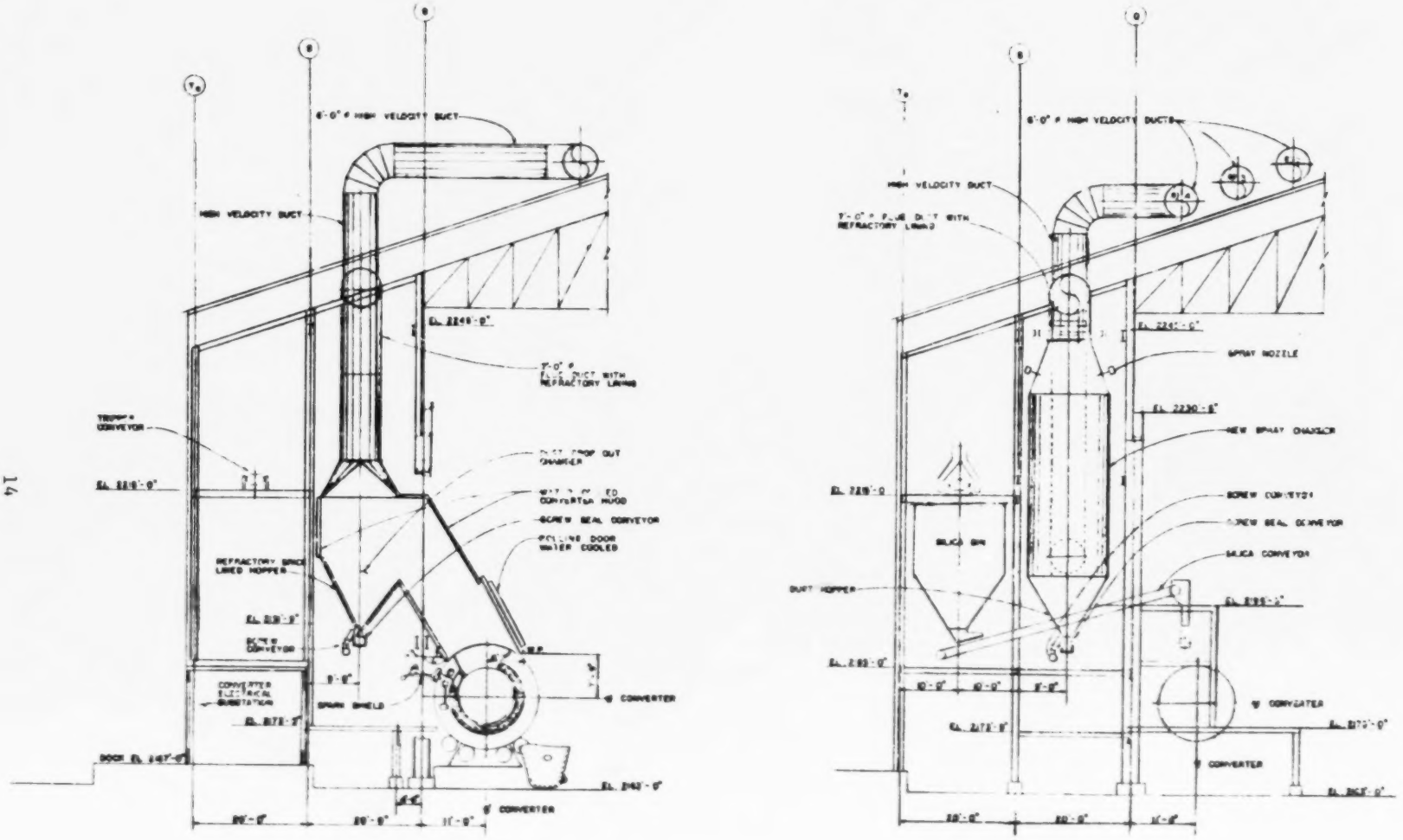
The converters were originally equipped with a mild steel hood with cast steel liners and a movable door to close at the front (Ref. 2). Each hood had a sliding gate-type damper leading into a common balloon flue. To meet air pollution regulations, Kennecott installed water-cooled hoods and gas coolers that enable operation with 50% (Reference 8) dilution of the gas. The new hood design is shown in Figure 7. The hood jackets, a plate type with T-bar dividers and stiffeners, are fabricated of 3/8 inch steel plate.

The water cooled portion includes the hood, the movable door, and the dust settling chamber extending up about 30 feet behind the converter. A 66-inch stainless steel flue channels the gas up, over, and down into the gas cooler where it flows concurrently with an ultrasonically dispersed water spray. The gas flows out of the bottom of the gas cooler, up out of the building and across to the induced draft fan plenum. Three bullseye dampers at the plenum entrance isolate converters from the draft fan. The fan discharge flows through an electrostatic precipitator before proceeding to the acid plant.

Each hood has a water flow of 1200 gallons per minute traveling from a 6 x 4 pump through the jackets to an air-to-water heat exchanger, and back to the pump. A condensate storage tank maintains a constant pressure at the pump suction. The water temperature rise in the hoods is between 20^{o} and 30^{o}F. The inlet water temperature is 140^{o}F and outlet is between 160^{o} and 170^{o}F.

The gas cooler is an unlined stainless steel vessel with eight Sonocore ultrasonic water sprays in the top. Inlet gas temperature is 1100^{o} - 1250^{o}F. The outlet gas is controlled at 700^{o}F by controlling the volume of water supplied to the sprays.

The draft control system is two-part. The ID fan plenum draft setting automatically controls the fan speed to maintain the plenum draft. Each converter also has a butterfly-trim damper down stream



ELEVATION VIEW OF WATER COOLED HOODS AND SPRAY COOLER

Figure 7.

of the gas cooler to maintain a draft setting at the top of the hood. This trim damper is activated with an air cylinder.

The dust recovery system consists of screw seals below the hood dust chamber and the gas cooler. These screws feed a gathering screw which discharges into a dust bin. The gathering screw and both converter screws are actuated by the converter blast air pressure and only run while the converter is blowing.

Loading and operation of the converters consists of the following: (Ref. 4).

Five ladles of matte
One hour blow
Fifteen tons of silica loaded through the hood
Three ladles of slag removed
Two ladles of matte removed (15 to 20 minutes)
Fifty minutes blow
Add 10 tons of silica
Remove one or two ladles of slag
Repeat to obtain 100 tons of copper per converter load.

The level of the converter is judged by the operator. Slag is continuously taken off until it appears that all of the iron sulfide has been removed by reaction with the slag. When the iron sulfide has been eliminated the copper blow starts. The copper sulfide is converted to copper and SO_2 during the copper blow. During the copper pour which takes approximately 30-40 minutes, the converter is rolled out and the blister copper is poured into large ladles which are picked up by a crane and poured into the holding and refining furnaces.

The converter hoods are pulled back leaving a gap of about one foot during slag tapping. The hood draft is curtailed by closing the plug type bullseye damper. When the hood is pulled completely back fuming can be seen from the mouth of the converter. A portable gas

heater is used in the converter mouth when the matte production is not keeping up with the converter production to maintain an acceptable internal converter temperature.

During the operation of the converter hood and damper system the following negative pressures have been measured at the converter hood: (Ref. 4).

-4.5" w.c. - normal open-acid fan on, converter on, damper open

-5.5" w.c. - converter roll out-acid fan on, converter off, damper closed

-9" w.c. - momentary when damper closes and converter continues to roll

The converter hood system has a fan which provides additional suction and is controlled by an automatic pressure sensor. The converter fan works in conjunction with the acid fan to provide sufficient suction to pull the gases into the collection system. All of the gases go to the acid plant.

d. Other Emitting Equipment

Material handling in the feed preparation area during crushing and screening operations generates particulate matter. Roto-clone dust collectors and cyclones control these dust emissions. Ladles holding matte and slag are sources of visible fugitive emissions. The five vertical Ellerman type lime kilns used in the lime plant produce particulates. Small quantities of SO_2, NO_x, and particulate are generated in the anode furnaces. The holding furnaces are usually blown during the night shift. According to plant operators, there is no smoke observed when pouring these furnaces into the casting molds. Water sprayed on the cast anodes once they have "frozen" to further cool them produces large quantities of steam. Leakage in ducts and at other pieces of equipment results in additional particulate and SO_2 emissions.

E. EXISTING CONTROL EQUIPMENT

Fluo-solids reactor and converter gases are treated for both particulate and SO_2 removal. Reverberatory furnace gases are treated for particulate removal only. The general arrangement of the control equipment is shown in Figure 3.

a. Particulate Control Equipment

Fluo-solids reactor gases pass through two parallel sets of 4 primary and 4 secondary Ducon cyclones with a reported dust collection efficiency of 96.6%. The gases are cooled from 1050°F to about 800°F, then enter the acid plant system where SO_2 removal and additional particulate removal is accomplished. Gases from the three converters are collected in close-fitting water cooled hoods and pass through a gas cooler and three high velocity flues to an electrostatic precipitator. The precipitator, manufactured by Western Precipitation Division of Joy Manufacturing Company, is a two chamber design with three fields in each chamber. At the precipitator the gas temperature is about 600°F. Converter gases then enter the acid plant system.

Reverberatory furnace gases after heat recovery in two waste heat boilers travel through a balloon flue to a Koppers Corporation electrostatic precipitator. The precipitator consists of four chambers each with three fields. The overall dimensions are 35 feet wide by 120 feet long by 11 feet-4 inches high. Each field is 7 feet -6 inches long. The gas velocity through the precipitator is approximately 5 feet per second. Following the precipitator, the reverberatory furnace gases are discharged from a 600 foot tall stack.

b. Acid Plant System

The original acid plant was built in 1967 - 1968. This plant was designed to handle 75,000 standard cubic feet of gas per minute.

The plant originally had a two-pass converter with a single absorbing tower. In 1973 the plant was rebuilt to increase the capacity to 100,000 standard cubic feet per minute. A new three-pass converter was installed with an interpass absorbing tower between the second and third passes. This not only increased the capacity but also increased the conversion efficiency from 96% to 99%.

The following description of the equipment and operation of the present acid plant was taken from Reference 2. The acid plant flow sheet is shown in Figure 8.

Gas Scrubbing and Cooling

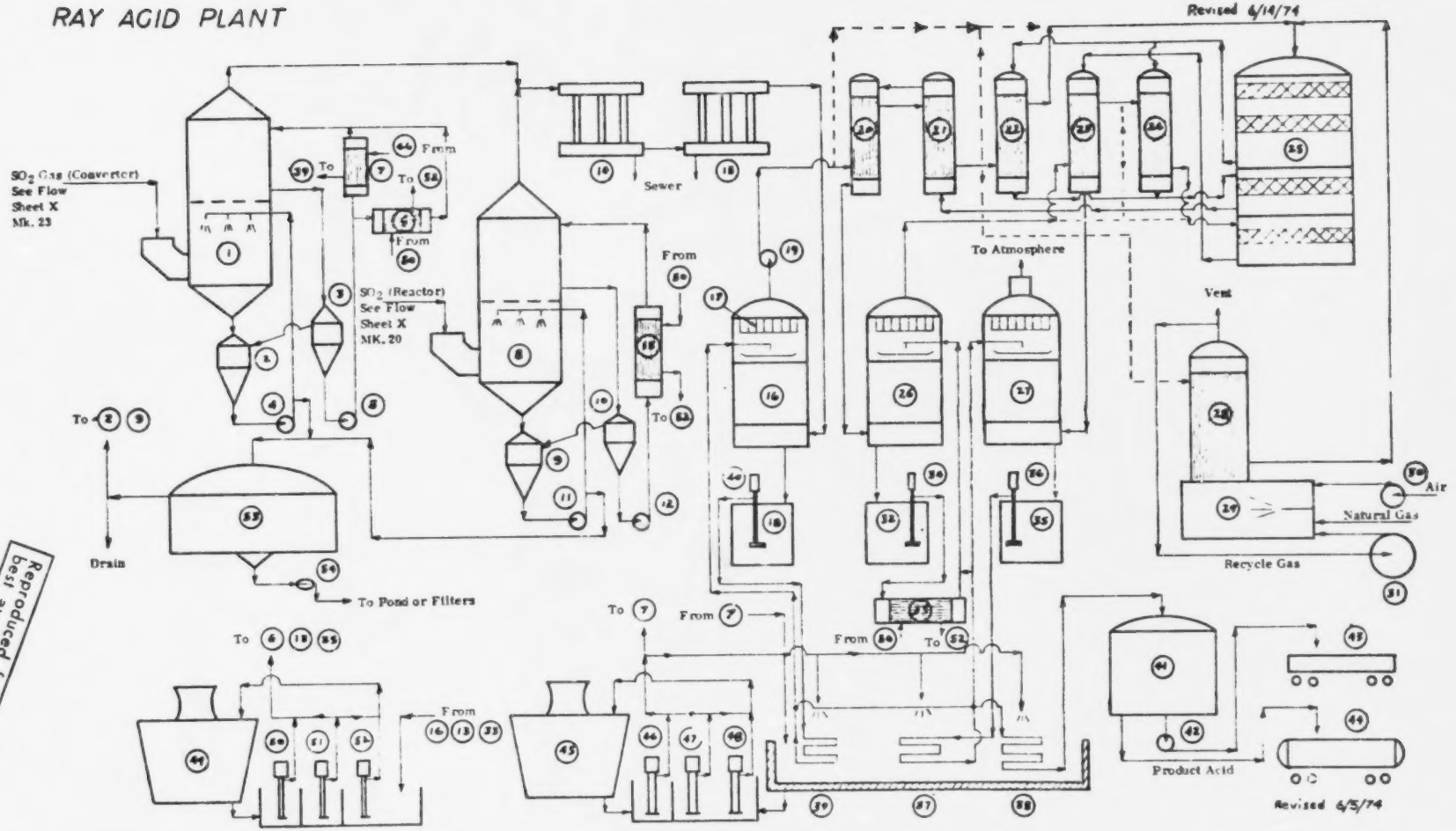
The scrubbing and cooling is done in two Peabody Towers. The smaller tower, designed to handle the fluo-solids roaster gas, is preceded by a Venturi scrubber. The Venturi scrubber is necessary because of the high dust loading of extremely fine dust. The larger tower is used to clean and cool the gas from the copper converters. The towers consist of two principal sections: One, a lower humidifying section constructed of mild steel plate and lined with brick and lead; two, an upper cooling section constructed of Alloy 20.

Hot gas enters the humidifying section and passes upward through a spray of weak acid from the spray nozzles in the top of the section. This spray removes the coarser solids from the gas and at the same time the heat in the gas evaporates water from the weak acid thus cooling the gas nearly to its adiabatic saturation temperature.

On leaving the humidifying section the gas then enters the cooling section which contains three Peabody impingement baffle grid assemblies mounted on the plate in such a manner as to provide an impact surface directly over each perforation. The gas flows upward through the perforations and is cooled by weak acid flowing across the perforated plates.

RAY ACID PLANT

FLOW SHEET XI
Revised 6/14/74



MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION
1	1	Converter Gas Scrubber	12	2	Upper Recycle Pump	23	1	Cold Interpass Heat Exchanger	34	2	Interpass Acid Pump	45	1	Primary Cooling Tower
2	1	Lower Recycle Tank	13	1	Mist Eliminator	24	1	Hot Interpass Heat Exchanger	35	1	Final Absorbing Acid Pump Tank	46	2	Coldwell Pump
3	1	Upper Recycle Tank	14	1	Mist Eliminator	25	1	Converter (Final Stage)	36	2	Final Absorbing Acid Pump	47	1	Standby Pump
4	2	Lower Recycle Pump	15	1	Mist Precipitator	26	1	Interpass Absorbing Tower	37		Final Absorbing Acid Coolers	48	2	Hotwell Pumps
5	2	Upper Recycle Pump	16	1	Drying Tower	27	1	Final Absorbing Tower	38		Product Acid Coolers	49	1	Secondary Cooling Tower
6	1	Heat Exchanger	17	1	Mist Eliminator	28	1	Preheat Heat Exchanger	39	1	Drying Tower Acid Coolers	50	1	Coldwell Pump
7	1	Cartrite Heat Exchanger	18	1	93% Acid Pump Tank	29	1	Combustion Chamber	40	2	Drying Tower Acid Pump	51	1	Standby Pump
8	1	Reactor Gas Scrubber	19	1	SO_2 Blower	30	1	Combustion Air Fan	41	4	Acid Storage Tanks	52	1	Hotwell Pump
9	1	Lower Recycle Tank	20	1	No. 1 Cold Heat Exchanger	31	1	Recycle Fan	42	3	Acid Loading Pumps	53	1	Sludge Thickener 50' Dia.
10	1	Upper Recycle Tank	21	1	No. 2 Cold Heat Exchanger	32	1	Interpass Acid Pump Tank	43		Truck Haulage to Pay	54	2	Diaphragm Pumps
11	2	Lower Recycle Pump	22	1	Hot Heat Exchanger	33	1	Interpass Acid Cooler	44		Rail Haulage			

Figure 8

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The weak acid from the cooling section flows to a pump tank and is then recirculated by a pump through coolers back to the top of the cooling section.

All the make-up water is added to this pump tank to control the concentration of chlorides, percent acid, and other impurities in the weak acid circulating solutions. The overflow from the cooling section pump tank goes to the pump tank of the humidifying section.

Weak acid from the humidifying section sprays also flows to a pump tank and is recirculated. Weak acid is purged from the humidifying section by pump pressure through a level control valve to the effluent stripper.

The effluent water from the stripper flows to a sludge settler, where solids are removed and then overflows the settler with a portion returning to the lower circuit pump tank and the remainder to sewer. The settled solids are pumped from the bottom of the settler to the filter plant for recovery of the contained copper.

The cooled gas leaves the two Peabody scrubbers in FRP ducts which are combined before entering the mist precipitators.

Mist Precipitators

The mist precipitator consists of six units arranged so that the gas passes through three parallel trains of two precipitators in series. Each precipitator chamber consists of 170 ten-inch lead pipes in each of which is suspended a wire covered with star-shaped lead. The high voltage current is connected to the wires while the lead pipes are grounded. The mist-laden gas enters the bottom of the chamber and flows up through the lead pipes. The mist and solids precipitate on the lead pipes where they are drained to the bottom of the chamber. The gas then leaves the upper section of the chamber substantially free of acid mist and solids. Each train

has a safety seal constructed into the bottom of the mist precipitator. The seal is so constructed that air is admitted to the gas stream if the suction reacnes 26 inches water gauge differential and thereby protects the lead chambers from excessive suction. The gas goes from the mist precipitators to the entrance of the drying tower.

Drying and Absorbing Acid System

The drying tower removes water vapor from the SO_2 gas stream before it passes to the converter and absorbing systems. Drying eliminates the corrosive action of wet SO_2 gas, reducing possible damage to the catalyst.

The drying, interpass and final absorbing towers are nearly identical in construction. Each is a vertical, cylindrical, brick-lined chamber containing ceramic packing supported by brick grid bars resting on brick piers. Each tower also has a Brink Mist Eliminator located above the acid distributors in the tower top to remove any acid mist particles in the gas stream. Cast iron troughs distribute circulated acid uniformly into the packing. The gas flow is upward through the towers countercurrent to the acid distributed over the packing. Acid flows by gravity from each tower to a pump tank and is recirculated through coolers to the distributor troughs. Interconnecting piping between the tower units for the transfer of acid from one circulating system tc the other and dilution water inlet lines to the absorbing system are used to maintain the desired acid concentration for the towers.

The strength of the drying acid should be maintained at not less than 93% H_2SO_4 if possible. The acid strength in the absorbing towers should be maintained between 98-99% H_2SO_4. The temperature of the drying acid should be as low as practicable and never more than $130^{o}F$. The absorbing acids are maintained at about $170^{o}F$ for best results.

The gas goes from the drying tower to the main blowers.

Main Blowers

The purpose of the main blowers is to provide means for moving the process gas through the plant.

There are three blowers installed for parallel operations. Each blower is a single stage centrifugal type driven by a 2000 HP electric motor through a gear increaser. Each of the three blowers is equipped with an inlet control butterfly valve which is pneumatically operated from the main control panel. Depending on the amount of process gas available, one, two, or three blowers are operated.

The process gas goes from the main blowers into the converter system.

Converter System

The function of the converter is to effect the chemical reaction between sulfur dioxide and oxygen to form sulfur trioxide. The function of the catalyst is to accelerate the reaction, that is, to shorten the time required for the reaction to reach equilibrium. The catalyst is not itself affected or used up.

The converter system consists of an insulated, vertical, cylindrical vessel, known as a converter, five gas heat exchangers, and inter-connecting ducts. The converter contains four layers of vanadium catalyst arranged in three passes. The first pass consists of two layers, each remaining pass of one layer. The heat exchangers are insulated, vertical shell and tube units.

In operation, the flow of cold SO_2 gas from the blowers is through the shell side of two cold and one hot heat exchanger in series to the converter. The SO_2 gas preheated to operating temperature by utilizing the heat generated from the chemical reaction within the

converter. The preheated gas enters the top of the converter. The gas flow is downward through the catalyst layers with the gas leaving the converter after each pass for cooling. The arrangement for cooling is outlined as follows:

No. 1 pass (Upper 2 layers of catalyst), hot heat exchanger (tube side).

No. 2 pass (3rd catalyst layer), cooled in No. 1 and No. 2 cold heat exchangers (tube side) and reheated after the interpass absorption in cold interpass and hot interpass heat exchangers (shell side).

No. 3 pass (4th catalyst layer), cold interpass heat exchanger (tube side) before entering final absorbing tower.

A system of bypass ducts, with control valves around the cold and hot heat exchangers is provided for temperature control to the first and second passes and around the cold and hot interpass exchangers for temperature control to the third pass. Control valves at the tube side outlet of the hot and cold interpass exchangers are provided to control the split of the hot gas from the first pass through these exchangers.

Thermocouples are located in the inlet and outlet of each pass of the converter. The converter is operated by controlling the inlet temperature of each pass. Knowledge of the outlet temperature of each pass is also important as a means of determining the temperature rise and hence the amount of conversion done in each pass.

Pressure taps are provided at the inlet and outlet of each catalyst layer for field measurement of the pressure drop across the catalyst layer.

Direct Fired Preheater

The purpose of the preheater is to raise the temperature of the catalyst in the converter to a point at which conversion of SO_2 to SO_3 will occur. Operation of the preheater is required during starting of the plant after a shutdown or during periods of low gas

strength.

The preheater consists essentially of two parts: a brick-lined combustion chamber, and a tubular steel heat exchanger. The combustion chamber is fired with fuel to produce hot combustion gases which pass through the tubes in the heat exchanger. Air or SO_2 gas from the acid plant blowers passes around the tubes. Control dampers in the duct system are used to vary the amount of process gas through the preheater depending on the need of the plant. The preheater is kept on the line at all times because of frequent periods of low gas strength or volume.

Absorbing System

There are two absorbing towers in this plant -- the interpass absorber and the final absorber. The gas leaving the second pass of the converter passes through two heat exchangers and then to the interpass absorber. The SO_3 is absorbed from the gas stream leaving SO_2 to SO_3 in equilibrium so nearly all the remaining SO_2 can be converted in the final pass of the converter. The gas from the third pass then goes to the final absorber where the last traces of SO_3 are absorbed. This plant with the interpass absorber will give better than 99% conversion of SO_2 to SO_3.

For maximum absorption of SO_3 the circulating acid has to be between 98% and 99% in strength and the temperature between 160° and 180°F.

Acid Cooling

The absorption of water vapor in the drying tower and the constant addition of 98%-99% acid to the drying acid pump tank materially raises the temperature of the acid. Hence, this acid is pumped through cast iron coolers before delivering it again to the top of the drying tower because cool acid dries the process gas better than hot acid.

The absorption of SO_3 gas, the water or weaker acid added to the absorbing acid pump tanks, and the heat in the process gas, materially raises the temperature of the absorbing acids. Hence, this acid is also pumped through cast iron cooling coils before delivering it again to the top of the interpass and final absorbing towers so that it will not be too hot for efficient absorption.

The addition of dilution water to the absorbing acid, the absorption of SO_3 in the acid, and the absorption of water vapor by the drying acid constantly increases the volume of acid in the pump tanks. Hence, the product acid from the drying tower system must be pumped continuously to storage to maintain a constant level in the pump tanks.

The product is pumped through cast iron cooling coils to any of four 5000 ton storage tanks. The acid from the storage tanks can be loaded into either tank trucks or railroad cars.

Water Cooling System

The heat exchangers in the gas cooling section and in the acid cooling sections require a large volume of cooling water to maintain the desired temperatures. This water, after having been pumped through the heat exchangers and over the cooling coils, is then pumped over cooling towers to get rid of the excess heat.

F. GAS SYSTEM DUCTWORK

The gas system ductwork is shown in Figure 3, the general arrangement drawing. A few modifications in the ductwork have been made as noted below in the text. Reverberatory furnace gases, approximately 130,000 SCFM, enter the two waste heat boilers at approximately 2300°F and exit at 650°F. The heat is recovered by producing steam, 66,000 pounds per hour, at 450 psig and 750°F. The furnace gases are then carried by balloon flue to the four chamber Koppers precipitator. The dimensions of the balloon flue are

13" - 0½" by 13' - 0½". The length of the balloon flue between the waste heat boilers and the precipitator is approximately 180 feet. The gases travel through an additional 50 feet of ductwork before entering the 600 foot stack.

Fluo-solids reactor gases are carried in one of two gas ducts to the primary and secondary cyclones. It was necessary to blank off one of the gas ducts, thereby doubling the gas velocity in the other, to minimize dust buildup and plugging problems in the ductwork preceding the cyclones. The cyclones collect approximately 85% of the calcines from the reactor for feed to the reverberatory furnace. The reported overall efficiency of the cyclones is 96.6% (Ref. 2). Following the cyclones, the gases pass through a duct to a gas cooler, and then a bypass around the original calcine precipitator. The original calcine precipitator, shown in the general arrangement, has been bypassed by a high velocity flue. The bypass was installed because air infiltration into the precipitator caused burning of the residual sulfur which resulted in plate warpage. A Venturi scrubber was installed preceding the Peabody scrubber to handle the high dust loading of extremely fine dust. The reactor gases are then treated in the smaller of two Peabody scrubbers before entering the acid plant.

Converter gases are collected in water-cooled hoods and travel through approximately 180 to 200 feet of ductwork (4 feet inside diameter) to the blower. From the blower the converter gas travels through a 75 inch diameter duct to the two chamber Western Precipitation Division, Joy Manufacturing Company precipitator. Following the precipitator the gases are ducted to the larger Peabody scrubber and then on to the acid plant.

G. SULFUR BALANCE AND GAS COMPOSITION AT SYSTEM EXIT

Typical sulfur balance data are presented in Table 1. (Ref. 6). Of the 361 TPD of sulfur entering the smelter approximately 33 TPD (18 TPD fugitive and 15 TPD stack emissions) are emitted to the at-

Sulfur Input	Fluo-Solids Roaster		Reverb		Converter		Slag and Solid Waste	Fugitive Emissions	Present Sulfur Captured	Stack Emissions
TPD-S	$\%SO_2$	TPD-S	$\%SO_2$	TPD-S	$\%SO_2$	TPD-S	TPD-S	TPD-S	TPD-S	TPD-S
361	13	180	0.5	32	6-7	144	5	18	328	15

Table 1. KENNECOTT COPPER COMPANY/HAYDEN SMELTER - TYPICAL SULFUR BALANCE SUMMARY

mosphere. Presently 328 TPD of sulfur is captured (323 TPD captured in the acid plant and 5 TPD contained in slag and solid wastes). The "overall" sulfur removal efficiency of the smelter is therefore;

$$\frac{328}{361} \times 100\% = 90.9\%$$

Most of the stack SO_2 emissions are generated in the reverberatory furnace and are emitted from the 600 foot stack. At the main stack exit the following gas characteristics are typically encountered:

Gas volumetric flow	130,000 SCFM
Gas temperature	359°F
SO_2 concentration	0.4%
Dust loading	0.04 grains/SCF

The sulfur dioxide emission rate from the main stack varies from 0 to 8000 pounds per hour for periods of less than an hour. The average emission rate based on 24 hourly emission measurements per day for July 1974 was 1973 pounds per hour (23.7 TPD-SO_2) (Ref. 5).

Acid plant tail gas accounts for approximately 1 TPD of sulfur emissions. At the exit of the 100 foot and plant stack the gas temperature is typically 175°F.

The sulfur dioxide emission rate from the acid plant may vary from 0 to 2,000 pounds per hour for brief periods during startup when the catalyst beds are cold. However, these extremes occur only during upset conditions. The average hourly emission rate based on 24 hour average hourly emissions for 11 days in July 1974 was 237 pounds per hour (2.8 TPD-SO_2). (Ref. 2).

Fugitive emissions cannot be accurately measured, but are estimated to be 5% of the input sulfur. Sources of fugitive emissions are the slag skim bay, matte runners, waste heat boilers, and converter hood doors.

Converter dust collected in the precipitator was analyzed and reported to contain the following:

Cu	16.2%
Pb	7.1%
Zn	4.0%
Cd	1.3%
Mo	1.0%
Fe	24.1%
S	11.4%
Insolubles	15.6%

H. GAS CHARACTERISTIC VARIATION

It can be expected that SO_2 concentration in the offgas from the reverberatory furnace will vary significantly with time. This results from the variation in time required for decomposition or reaction of the various sulfide ores charged to the furnace. This variation in SO_2 content has been known to vary as much as 10 to 1 within a given charging time cycle. While no data are yet available from this smelter concerning this point, it should be considered for control system design.

SO_2 concentration in the converter offgas will also vary considerably for an entirely different reason. The operation of a converter includes several, usually three, slag blows and one copper blow. Between these blows the converter is not blowing the hood above the converter is closed off by dampers so that the gases do not pass through the collection system to the acid plant. The attempt is always made to maintain at least one converter blowing gases into the system at any given time. Usually a converter will be provided with 20,000 SCFM to the tuyeres. An additional 50% of dilution air is estimated to be added to this gas flow resulting in a total gas flow from each converter in the range of 30,000 SCFM.

When a converter is blowing there will usually be approximately 30,000 SCFM at an SO_2 content in the range of 4.0 to 4.5%.

The fluo-solids reactor generates about 25,000 SCFM of gas with an SO_2 concentration of approximately 13%. Operation of the roaster/reactor is relatively constant. After cooling and initial dust removal, the reactor offgases are treated in the acid plant. Shutdown for cleaning of the reactor air distribution plate can take up to 14 hours every month.

Because of the normal fluctuation in converter feed and operation, the SO_2 concentration can vary over a relatively wide range. In addition, the gas volume flow from the converter line to the acid plant can vary over a wide range from maximum to zero. Operation of the control system must be conducted in a manner to compensate for these fluctuations. Acid plant operation at this smelter appears to be typical providing satisfactory control. The acid plant operates at approximately 5 to 10% downtime.

I. STACK DESCRIPTION

Main Stack (Reverberatory Stack)*

Height	600 feet
Diameter (ID)	39 feet, base 17 feet 2-3/8", top
Stack gas temperature (average)	359°F
Stack gas exit velocity (calculated)	1050 fpm
Base elevation above MSL	2204 feet

Acid Plant Tail Gas Stack

Height	100 feet
Diameter (ID)	8 feet
Stack gas temperature (average)	175°F
Stack gas exit velocity (calculated)	2000 fpm
Base elevation above MSL	2204 feet

*Reference 7.

J. PRESENT TECHNIQUE FOR SOLID WASTE HANDLING

Reverberatory furnace slag is hauled in slag cars to the slag dump at an average rate of 650 TPD. Converter slag is not returned to the reverberatory furnace, but is allowed to cool slowly, crushed, and sent to a flotation mill to recover copper. The concentrate is dewatered and sent back to the fluo-solids roaster. Waste material from the sulfide flotation process is partially dewatered in thickeners and then pumped to the tailings pond. Sludge from the two Peabody scrubbers is returned to the fluo-solids roaster. Overflow from the scrubbers is pumped to the tailings pond. Dust collected in the reverberatory furnace waste heat boilers is collected in hoppers and hauled by a front end loader to the converter. Dusts from the reverberatory furnace which are collected in the balloon flue and electrostatic precipitator are transported by screw conveyor to the east calcine bin and then back into the reverberatory furnace. Likewise, converter flue dust collected in the electrostatic precipitator is returned to the furnace.

K. FOOTING AND STRUCTURAL REQUIREMENTS

No local codes apply. Seismic zone 2, wind load 20 PSF and snow load 20 PSF are used for design.

Soil testing should be assumed to determine footing requirements.

L. EXISTING AND AVAILABLE UTILITIES

Water is obtained from wells. It is expected that future gas supplies be limited. Additional electricity beyond present capacity will be available from public utility unless an electrical furnace is considered.

M. POTENTIAL NEW CONTROL EQUIPMENT INSTALLATION PROBLEMS

Except for available area to locate control equipment, no additional installation problems are apparent at this time.

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1. Kennecott Copper Corporation, Ray Mines Division, Permit IX

2. Kennecott Copper Corporation, Ray Mines Division, Hayden Smelter and Acid Plant Gas Handling System. Stocker J.E., Nelson D.E., and Mulholland LE. Presented at the Annual Meeting, AIME Tucson, Arizona, December 2, 1974.

3. Visit to Kennecott Copper Corporation, Hayden, Arizona, July 24, 1975.

4. Visit to Kennecott Copper Corporation, Hayden, Arizona, August 15, 1974.

5. August 29, 1974. Kennecott Copper Corporation memo to U.S. Environmental Protection Agency, Region IX

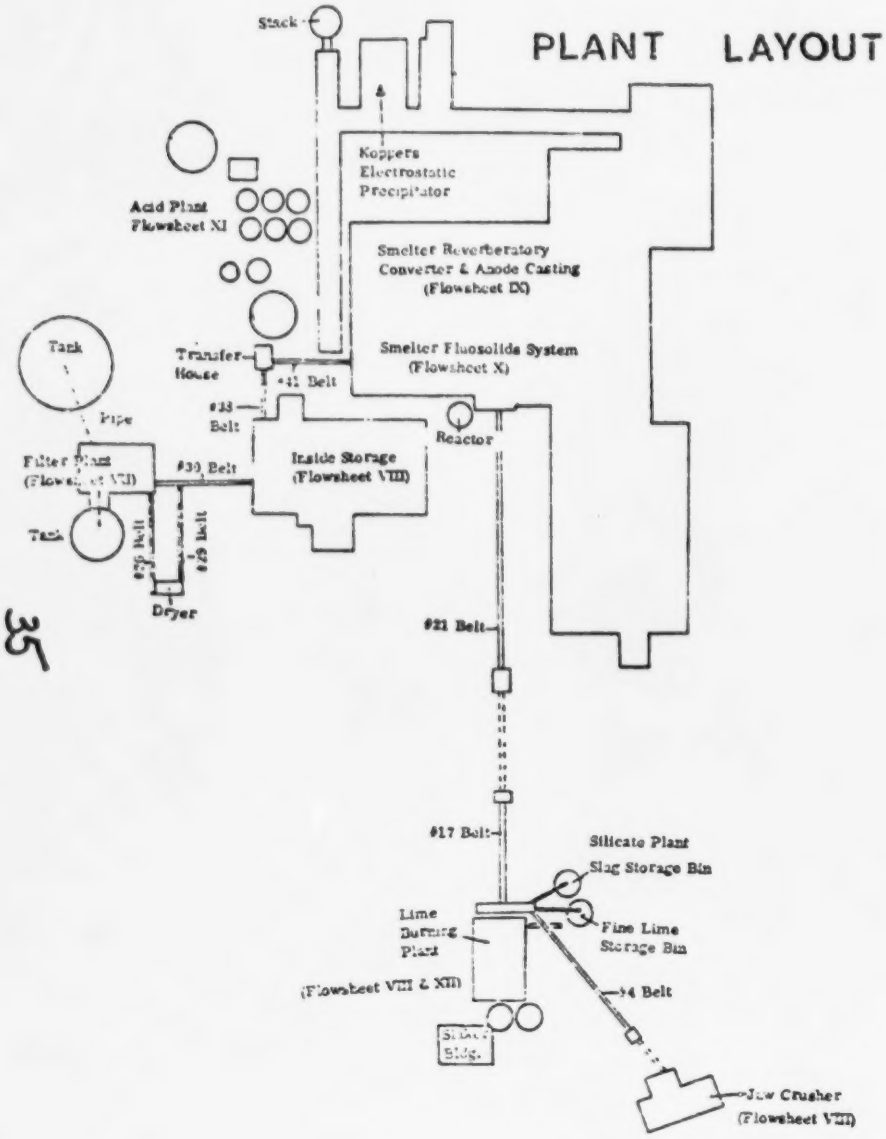
6. Evaluation of Controllability of SO_2 Emissions from Copper Smelters in the State of Arizona, Weisenberg I.J. and G.E. Umlauf, June 1975.

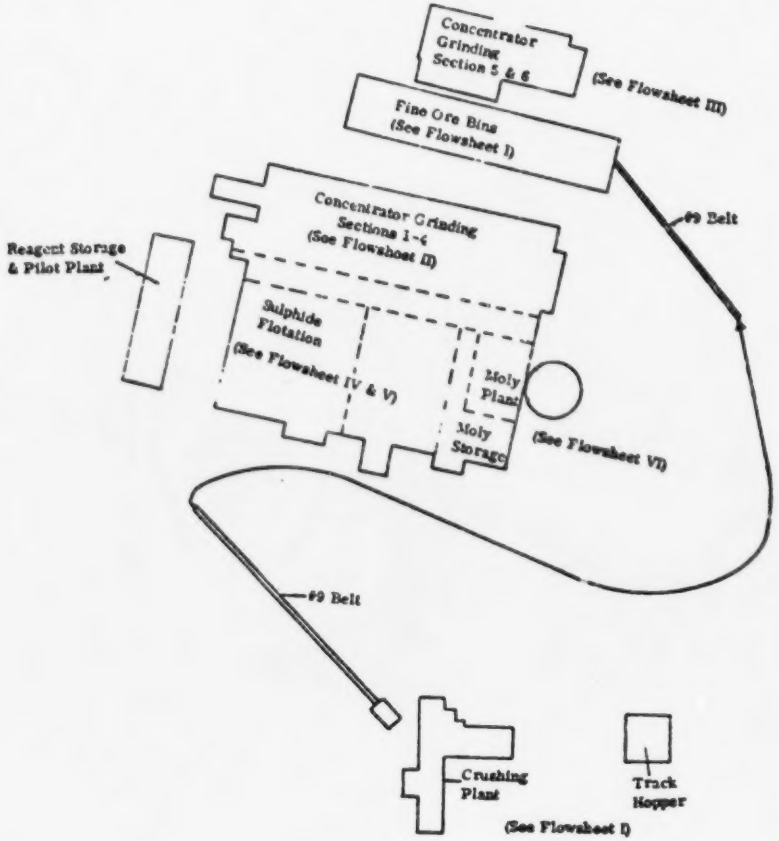
7. Kennecott Copper Corporation Correspondence with U.S. Environmental Protection Agency, Region IX, August 29, 1974.

8. Letter K.H. Matheson to I.J. Weisenberg, October 9, 1975.

APPENDIX

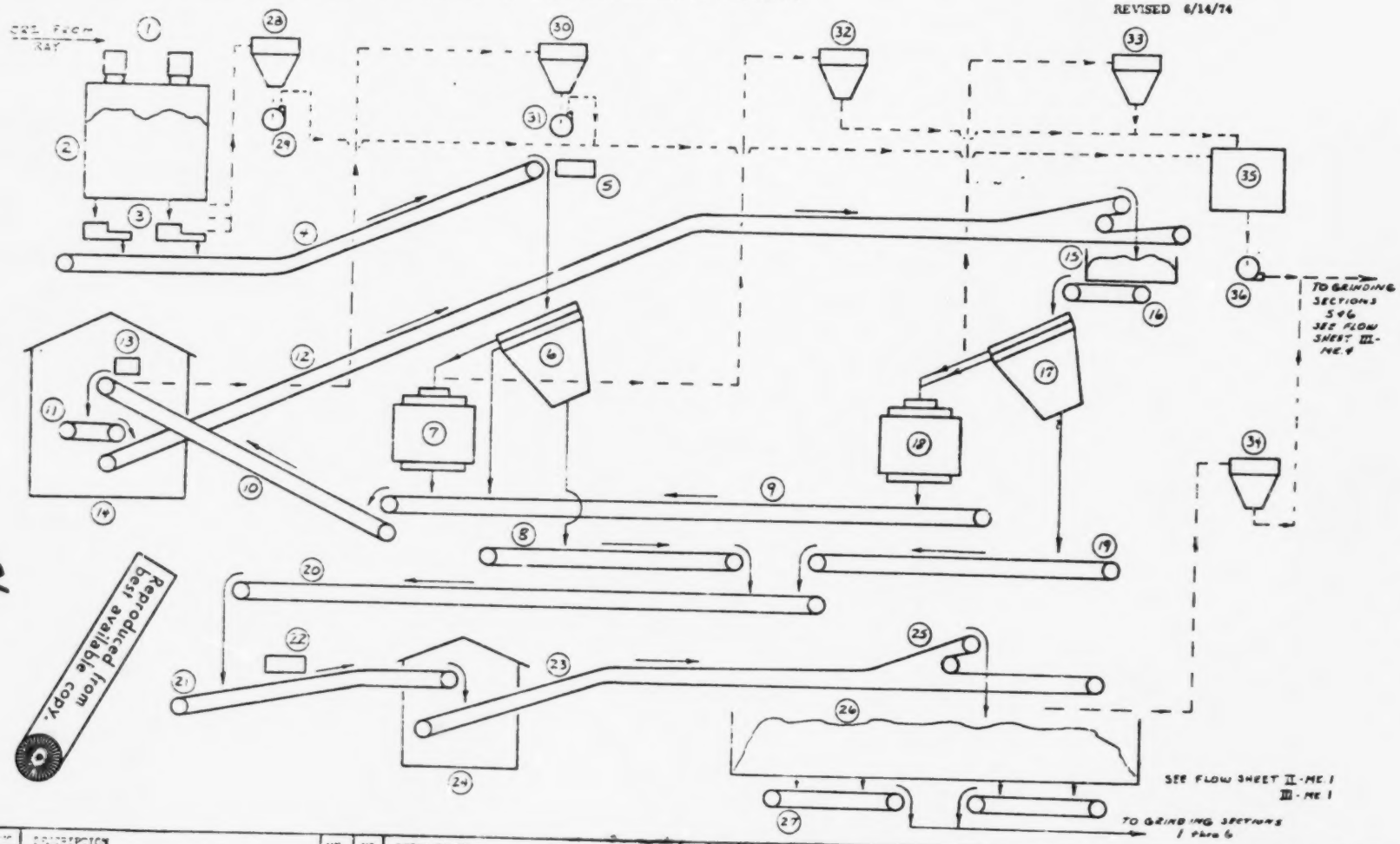
PLANT LAYOUT AND FLOWSHEET REFERENCE





RAY CONCENTRATOR - SECONDARY CRUSHING PLANT

FLOW SHEET I
REVISED 6/14/74



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NO	QTY	DESCRIPTION
1		100 Ton Ore Cars
2	1	1000 Ton Track Hopper
3	6	48" Reciprocating Plate Feeders
4	3	42" Belt Conveyor #1A, B, C
5	3	Dings Magnet
6	3	2x16 Twin Deck Screen - 6' x 20'
7	3	Standard Cone Crusher - 7'
8	1	42" Belt Conveyor #5
9	1	30" Belt Conveyor #2
10	1	120" Belt Conveyor #3

NO	QTY	DESCRIPTION
11	1	60" Belt Conveyor #4
12	1	60" Belt Conveyor #5
13	1	Dings Magnet
14	1	Transfer House
15	1	600 Ton Ore Bin
16	5	60" Belt Feeder, Variable Speed
17	5	Double Deck Screen - 6' x 20'
18	5	Short Head Cone Crusher - 7'
19	1	48" Belt Conveyor #7
20	1	42" Belt Conveyor #8

NO	QTY	DESCRIPTION
21	1	42" Belt Conveyor #6
22	3	Weightometer
23	1	48" Belt Conveyor #10
24	1	Transfer House
25	1	Dripper
26	1	Fine Ore Bin - 27,000 Tons Dead
27	12	42" Belt Feeder - Variable Speed
28	1	Cyclone Dust Collector
29	1	Pump, Slurry 3" x 3"
30	1	Roto-clone Dust Collector

NO	QTY	DESCRIPTION
31	1	Vertical Sand Pump
32	2	Roto-clone Dust Collector
33	3	Roto-clone Dust Collector
34	1	Roto-clone Dust Collector
35	1	Collecting Pump
36	5	Pump, Slurry

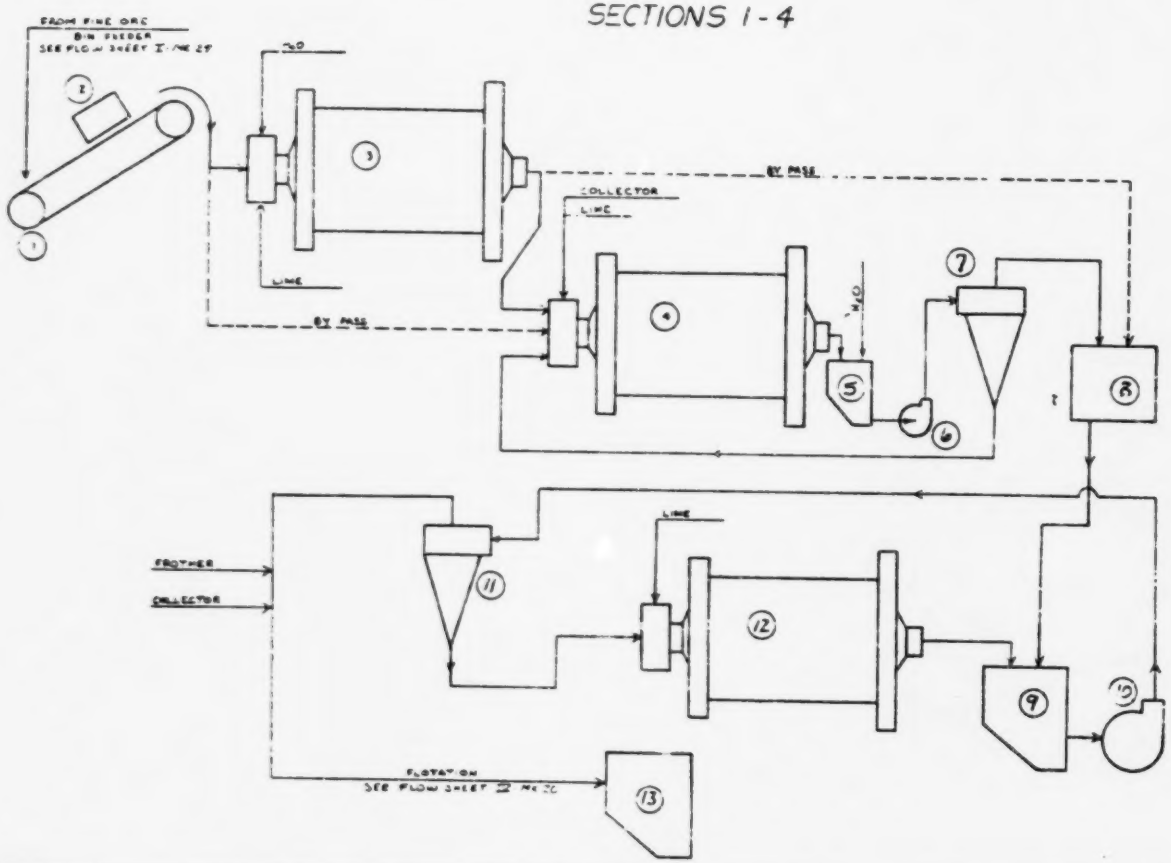
RAY CONCENTRATOR

GRINDING

SECTIONS 1 - 4

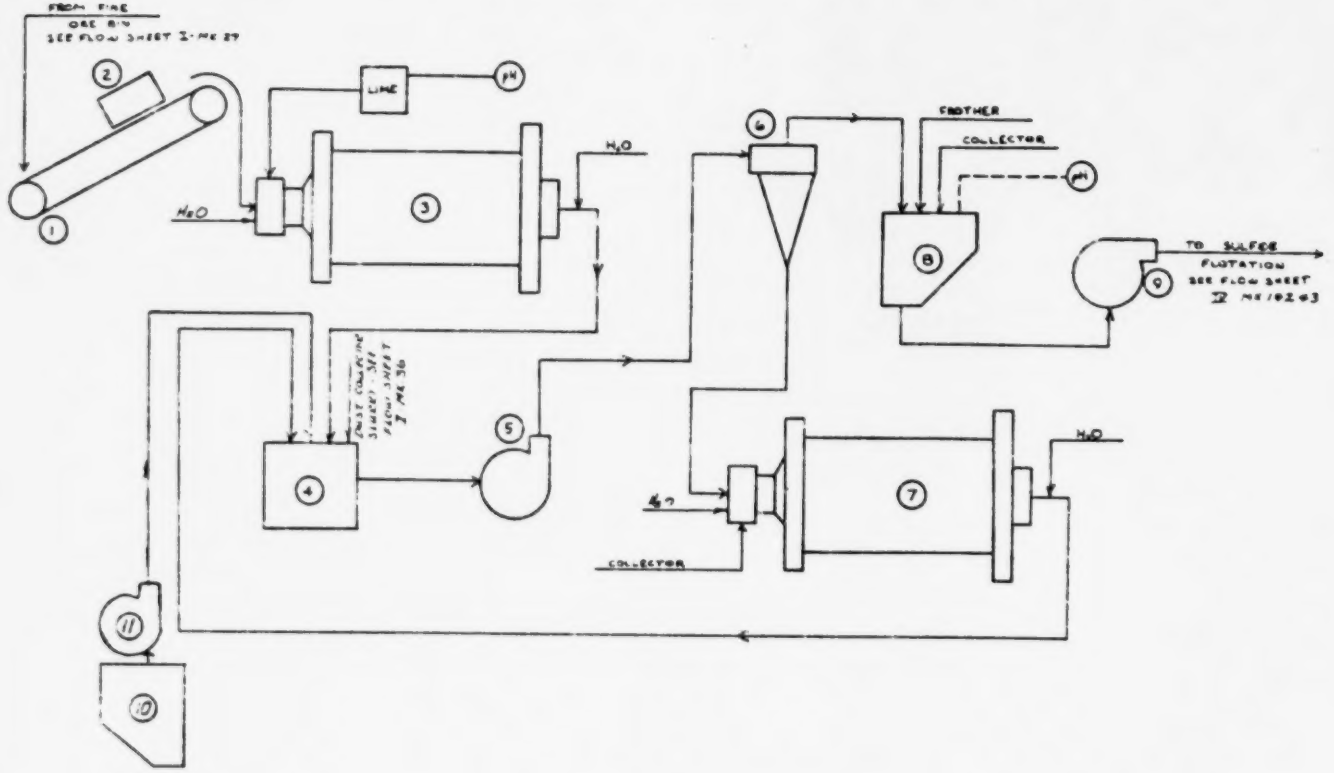
FLOWSHEET No. II

REVISED 6/14/74



RAY CONCENTRATOR
GRINDING SEC. 5&6

FLOWSHEET No. III
REVISED 6/14/74

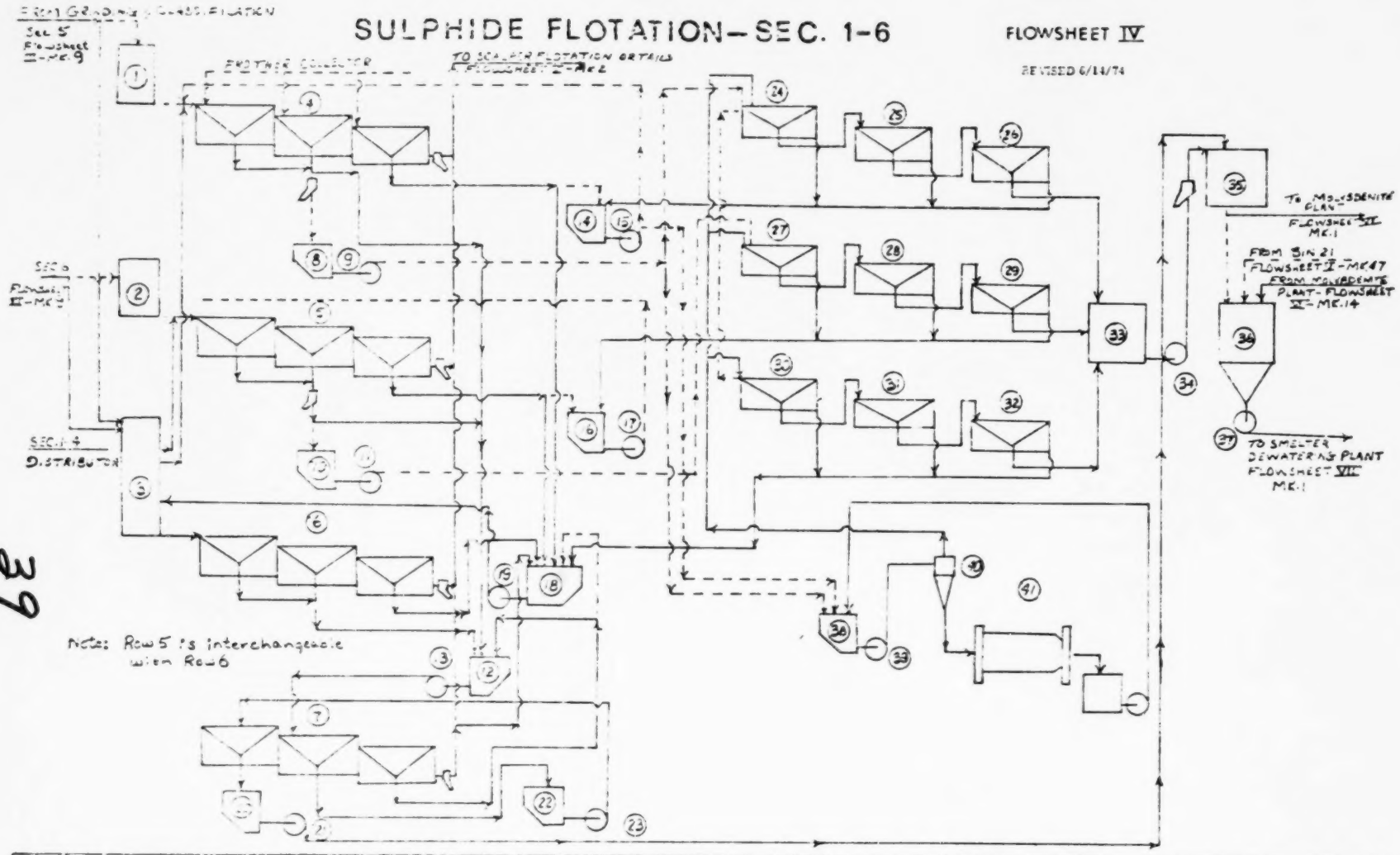


ITEM	QTY	DESCRIPTION	QTY	ITEM	DESCRIPTION	ITEM	QTY	DESCRIPTION	QTY	NO	DESCRIPTION
1	2	Inclined Conveyor Belt [illegible]	2	[illegible]	[illegible]						
	2	Weigh meter	1	1	Sk. 2						
3	1	Rod Mill 10 ft. 0" x 16'	11	2	Gallgher Vertical Pump						
4	1	Sump [illegible]									
5	1	Cyclone Feed Pump [illegible]									
6	1	Cyclone Assembly [illegible]									
7	1	Ball Mill [illegible]									
8	1	Conditioner [illegible]									

SULPHIDE FLOTATION—SEC. 1-6

FLOWSHEET IV

REVISED 6/14/74


ANOTHER COLLECTOR
TO SCAVENGER FLOTATION DETAILS FLOWSHEET I-MK 2
SEC 5 FLOWSHEET II-MK 9
SEC 6 FLOWSHEET II-MK 9
SEC 1-4 DISTRIBUTOR
TO MOLYBDENITE PLANT FLOWSHEET VII MK 1
FROM SIN 21 FLOWSHEET I-MK 47
FROM MOLYBDENITE PLANT-FLOWSHEET V-MK 14
TO SMELTER DEWATERING PLANT FLOWSHEET VII MK 1
Note: Row 5 is interchangeable with Row 6

NO.	NO.	DESCRIPTION	NO.	NO.	DESCRIPTION	NO.	NO.	DESCRIPTION	NO.	NO.	DESCRIPTION
1	1	Section 5 Distributor Box	11		3" x 4" Centrifugal Pumps	21	2	8" Centrifugal Pumps	31	4	44" Fag. 2nd Cleaner - Sec. 1-4
2	1	Section 6 Distributor Box	12	1	Rougher Concentrate Sump	22	1	Final Cleaner Concentrate Sump	32	3	44" Fag. 3rd Cleaner - Sec. 1-4
3	1	Section 1-4 Distributor Box	13		3" x 4" Centrifugal Pumps	23	2	8" Centrifugal Pumps	33	1	Final Concentrate Sump
4	11	Wemco 120 Mechanical Cells - Row 1	14	1	Scavenger Concentrate Sump, Sec. 5	24	3	54" Fag. 1st Cleaner - Sec. 5	34	2	6" Centrifugal Pumps
5	11	Wemco 120 Mechanical Cells - Row 2	15		6" x 6" Centrifugal Pumps	25	5	44" Fag. 2nd Cleaner - Sec. 5	35	1	Sampling Box
6	45	Wemco 120 Mechanical Cells - Row 3, 4, 5	16	1	Scavenger Concentrate Sump, Sec. 6	26	3	44" Fag. 3rd Cleaner - Sec. 5	36	2	Agitator (Steady Head) Tanks
7	15	Wemco 120 Mechanical Cells - Row 6	17	2	6" x 6" Centrifugal Pumps	27	3	54" Fag. 1st Cleaner - Sec. 6	37	6	6" x 6" Centrifugal Pumps
8	1	Rougher Concentrate Sump - Section 5	18	1	Primary Sulphide Feed Sump	28	4	44" Fag. 2nd Cleaner - Sec. 6	38	1	Regrind Pump Sump
9	2	5" x 4" Centrifugal Pumps	19	5	10" x 8" Centrifugal Pumps	29	3	44" Fag. 3rd Cleaner - Sec. 6	39	3	10" x 8" Centrifugal Pumps
10	1	Rougher Concentrate Sump - Section 6	20	1	1st Cleaner Concentrate Sump	30	3	54" Fag. 1st Cleaner - Sec. 1-4	40	6	Krebs D20B Cyclones
									41	1	Test Regrind Circuit (two 7'x10' Ball Mills)

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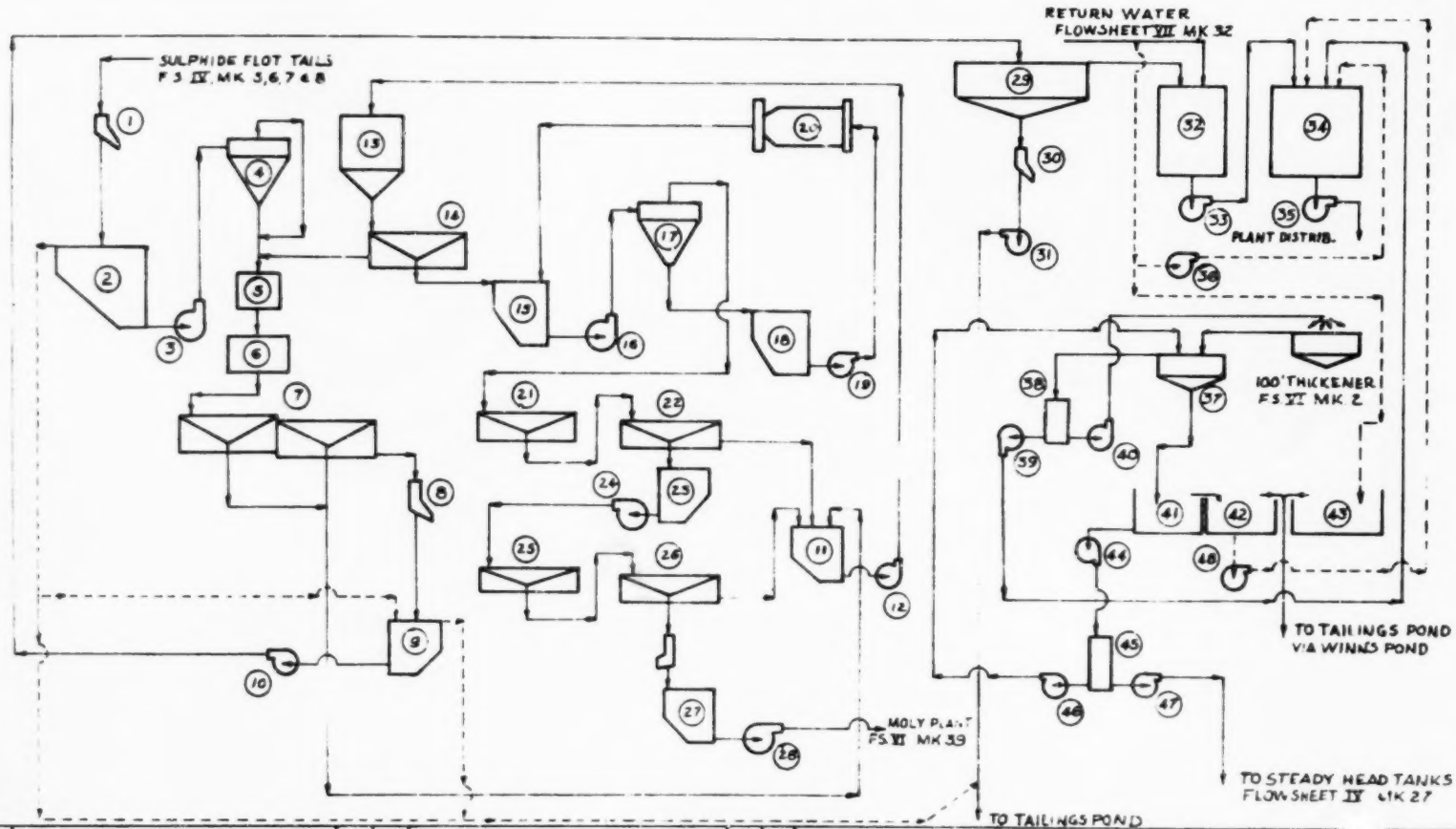
SCALPER FLOTATION

FLOWSHEET V

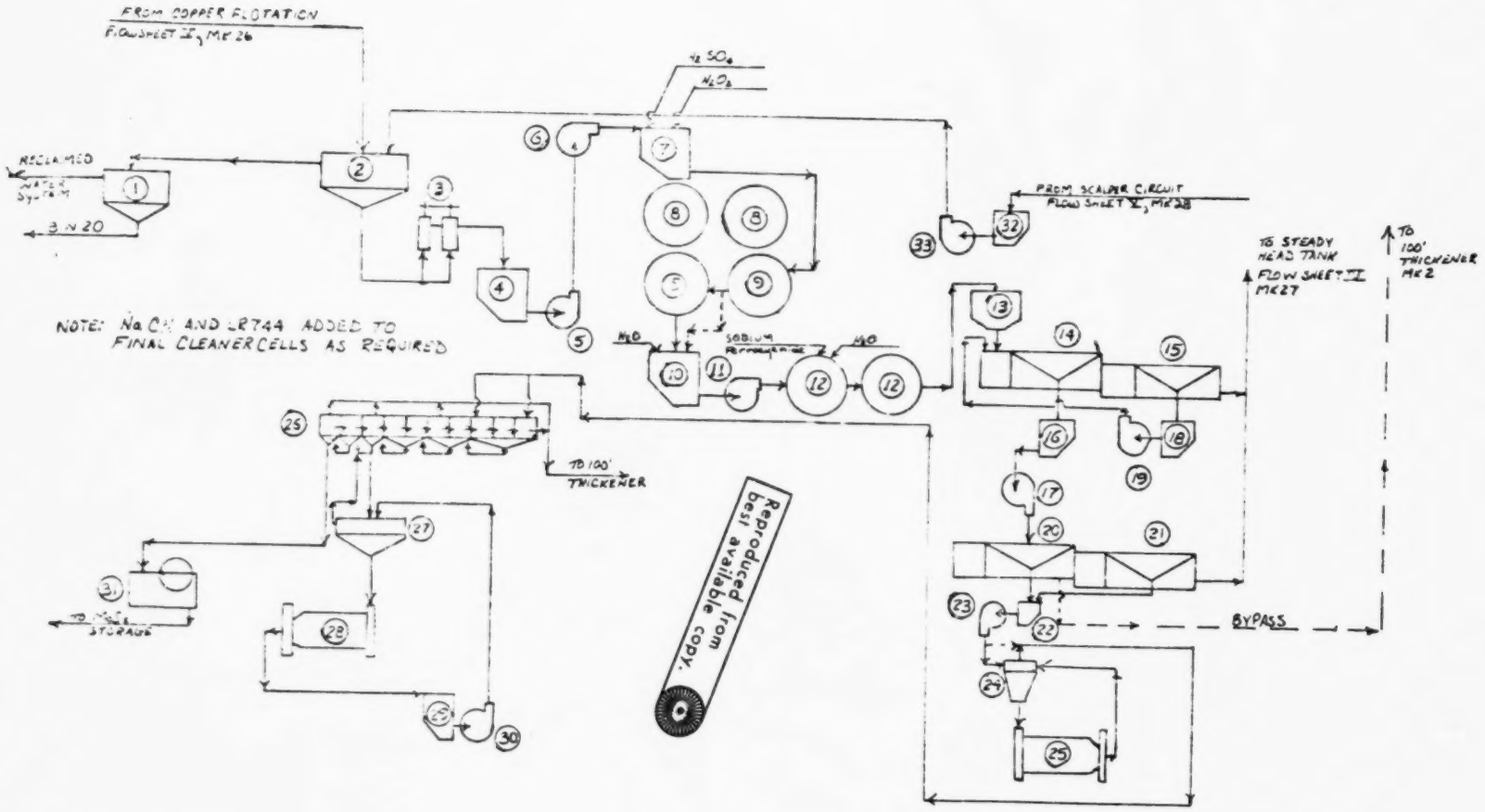


MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION
1	1	Sampler	13	1	Distributor Box	25	4	Fag 4th Cleaner 44	37	1	75' Thickener
2	1	Pump Sump	14	6	Fag. 1st Cleaner 56"	26	3	Fag 5th Cleaner 44	38	1	Pump Sump
3	5	8" Centrifugal Pumps	15	1	Pump Sump	27	1	Pump Sump	39	1	6" Centrifugal Pump
4	15	220 Krebs Cyclones	16	1	6" Centrifugal Pumps	28	2	4" Centrifugal Pumps	40	1	6" Centrifugal Pump
5	1	Collecting Box	17	2	10" Krebs Cyclone	29	1	45' Thickener	41	1	Bin 20
6	1	Distributor Box	18	1	Pump Sump	30	1	Sampler	42	1	Bin 21
7	12	Rove Cell w Cells 2-70'	19	2	3" Centrifugal Pumps	31	1	16" x 14" Centrifugal Pumps	43	1	Bins 10 to 16
8	1	Sampler	20	1	7' x 10' Regrind Ball Mill	32	1	20' Surge Tank	44	1	4" Centrifugal Pump
9	1	Pump Sump	21	4	Fag 2nd Cleaner 44	33	2	10" Centrifugal Pumps	45	1	Pump Sump
10	3	5" x 5" Centrifugal Pumps	22	3	Fag 3rd Cleaner 44	34	1	40' Storage Tank	46	1	4" Centrifugal Pump
11	1	Pump Sump	23	1	Pump Sump	35	4	8" x 6" Centrifugal Pumps	47	1	4" Centrifugal Pump
12	1	8" Centrifugal Pump	24	1	4" Centrifugal Pumps	36	1	3" Centrifugal Pumps	48	1	6" Centrifugal Pump

RAY CONCENTRATOR MOLYBDENITE PLANT

FLOWSHEET VI

REVISED 6/10/74


FROM COPPER FLOTATION
FLOWSHEET II, MK 26
RECLAIMED WATER SYSTEM
B IN 20
NOTE: Na CN AND LR744 ADDED TO FINAL CLEANER CELLS AS REQUIRED
MO
SODIUM HYDROSULFIDE
TO 100' THICKENER
TO MO STORAGE
FROM SCALPER CIRCUIT FLOW SHEET V, MK 28
TO STEADY HEAD TANK FLOW SHEET II MK 27
TO 100' THICKENER MK 2
BYPASS

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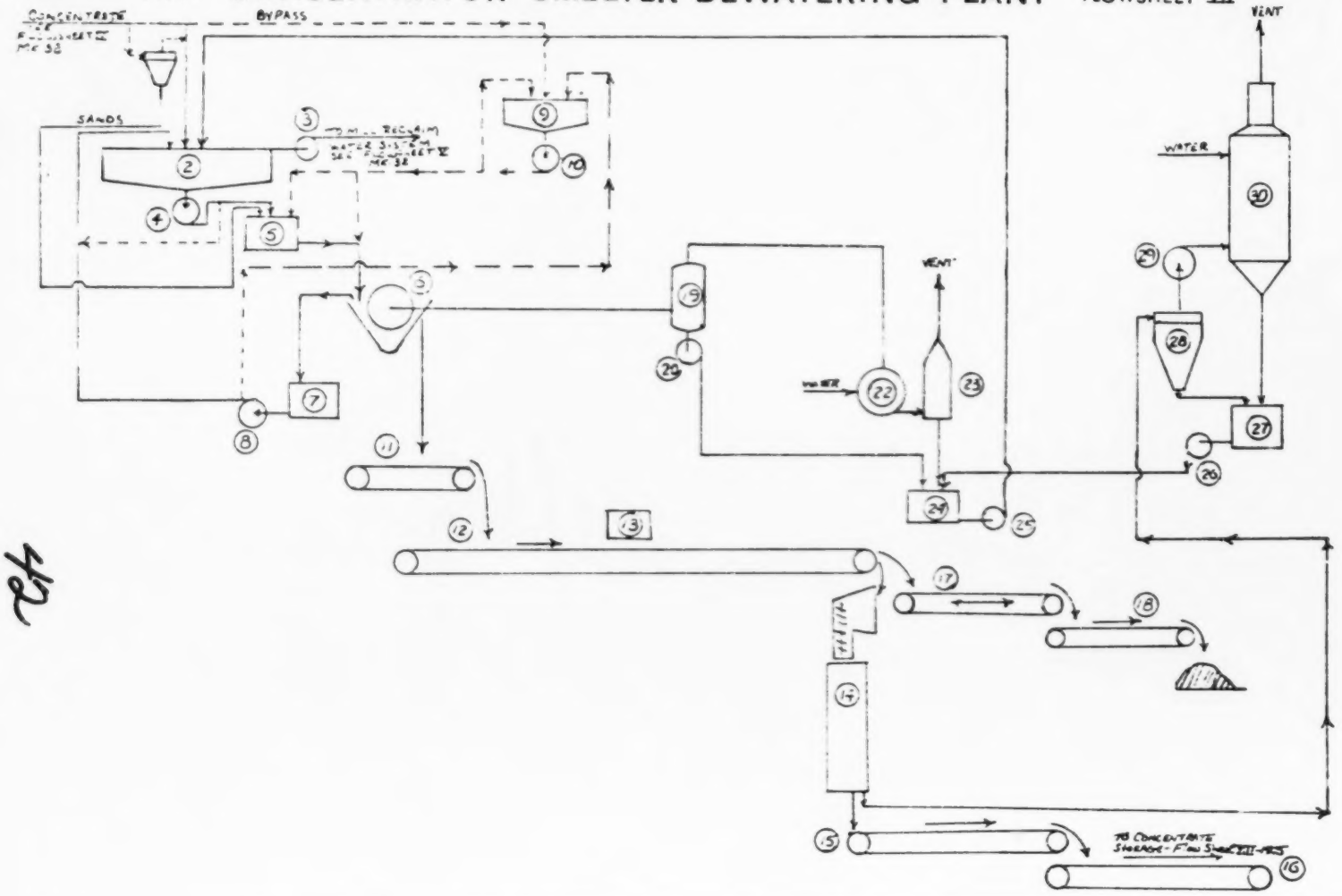
MK	NO.	DESCRIPTION	MK	NO.	DESCRIPTION	MK	NO.	DESCRIPTION	MK	NO.	DESCRIPTION
1	1	75' Thickener	12	2	Roughor Conditioners	23	2	2" Centrifugal Pumps			
2	1	100' Thickener	13	1	Distributor Box	24	1	Krebs D6B Cyclone			
3	2	Denver Duplex Pumps	14	2	Roughor Flotation Rows - Gallgher #35	25	1	Regrind Ball Mill			
4	1	Pump Sump	15	2	Scavenger Flotation Rows - Gallgher #39	26	10	18S Denver Counter Current Cleaner			
5	2	4" x 6" Centrifugal Pumps	16	1	Pump Sump	27	1	Hydro - Separator			
6	2	4" x 6" Centrifugal Pumps	17	2	4" x 6" Centrifugal Pumps	28	1	Regrind Ball Mill			
7	1	Pump Sump	18	1	Pump Sump	29	1	Pump Sump			
8	2	Steam Tubes Nutting Lifts	19	2	3" Centrifugal Pumps	30	2	2" x 3" Centrifugal Pumps			
9	2	Agitation Tanks	20	1	1st Cleaner Row - Gallgher #38	32	1	6' x 4' Disc Filter			
10	1	Pump Sump	21	1	1st Cleaner Scalper Row	33	1	Pump Sump			
11	2	4" x 6" Centrifugal Pumps	22	1	Pump Sump	33	1	5" Vertical Pump			

RAY CONCENTRATOR SMELTER DEWATERING PLANT FLOWSHEET VII

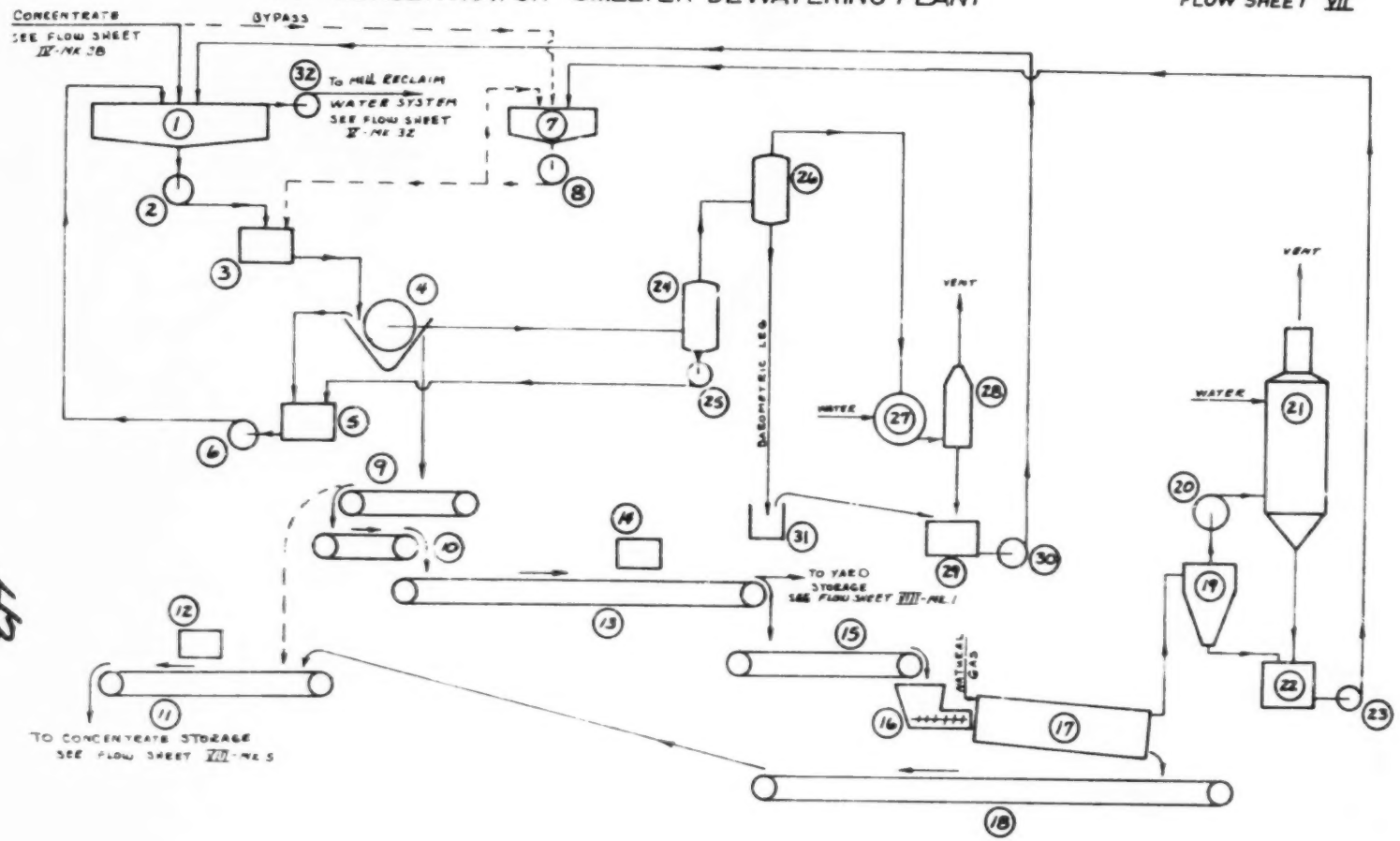
REVISED 6/13/74



MK	NO.	DESCRIPTION	MK	NO.	DESCRIPTION	MK	NO.	DESCRIPTION	MK	NO	DESCRIPTION
1	1	Cyclone	10	1	Pump 3 x 3	19	6	Receiver	28	1	Cyclone
2	1	100' Diameter Thickener	11	1	24" Conveyor Belt, #24	20	6	Filtrate Pump	29	1	ID Fan
3	2	Pump 6 x 6	12	1	24" Conveyor Belt, #26	21	1	Seal Tank	30	1	Scrubber
4	2	Pump	13	1	Merrick Scale	22	2	Vacuum Pump			
5	1	Sump	14	1	Screw Conveyor and Bucket	23	1	Moisture Separator			
6	2	Disc Filter 6 x 6	15	1	24" Conveyor Belt, #29	24	1	Sump			
7	1	Sump	16	1	24" Conveyor Belt, #30	25	1	Pump (vertical) 4"			
8	2	Pump 6 x 6	17	1	24" Conveyor Belt, #31	26	1	Pump 3"			
9	1	80' Diameter Thickener	18	1	24" Conveyor Belt, #27	27	1	Sump			

RAY CONCENTRATOR SMELTER DEWATERING PLANT

FLOW SHEET VII

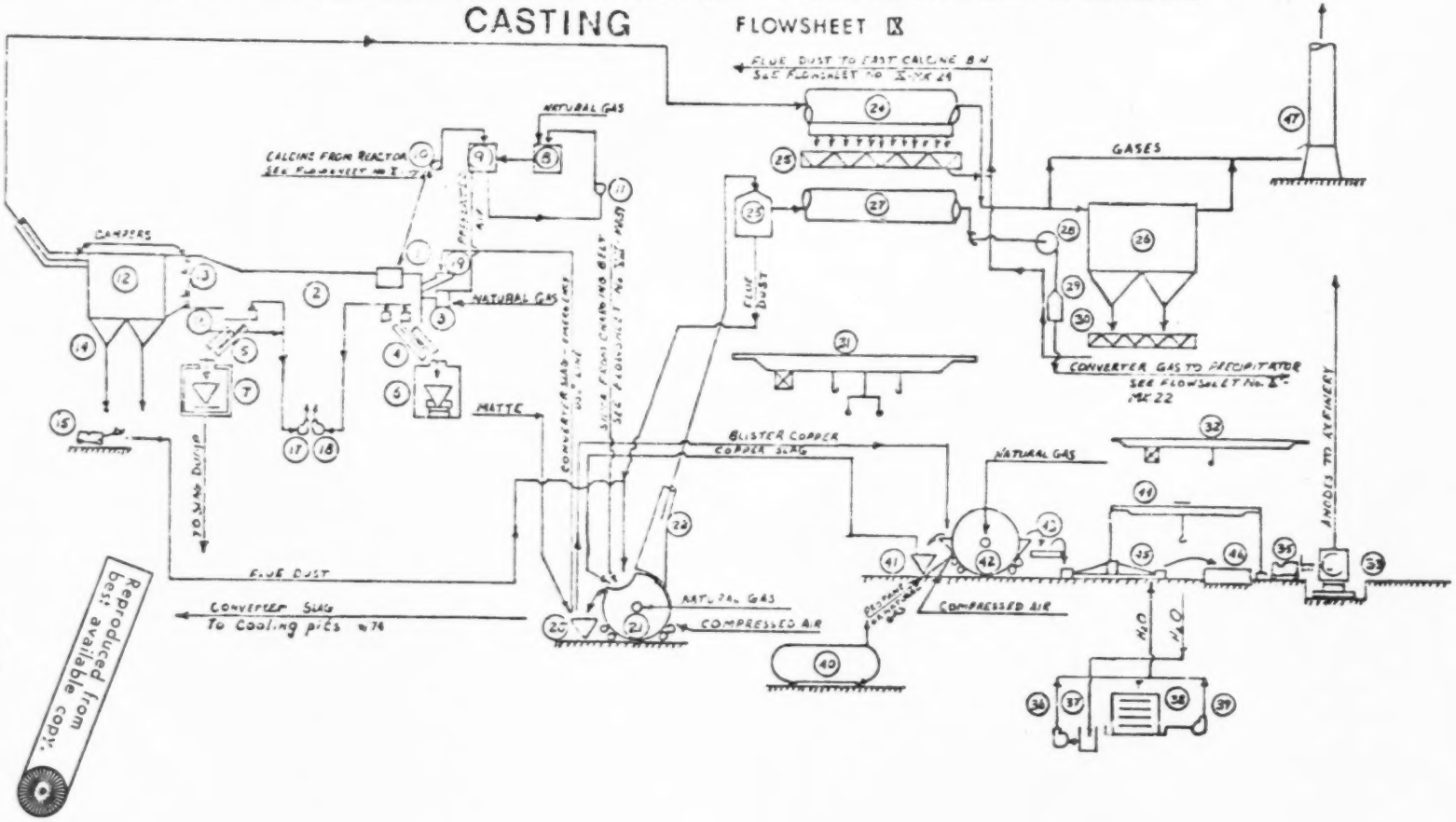


NK	NO	DESCRIPTION	NK	NO	DESCRIPTION	NK	NO	DESCRIPTION	NK	NO	DESCRIPTION
1	1	160' Diameter Thickener	10	1	24" Conveyor (Buttle Belt #5	19	1	Cyclone	28	4	Moisture Separator
2	2	Pump 1 x 3	11	1	24" Conveyor Belt #30	20	1	I D Fan	29	1	Sump
3	-	Sump	12	1	Merrick Scale	21	1	Scrubber	30	1	Pump (Vertical) 4"
4	3	Disc Filter 6 x 5	13	1	24" Conveyor Belt #5	22	1	Sump	31	1	Seal Tank
5	1	Sump	14	1	Merrick Scale	23	1	Pump 2"	32	2	Pump 2 x 3
6	2	Pump 6 x 5	15	1	24" Conveyor Belt #28	24	-	Receiver			
7	1	24' Diameter Thickener	16	1	Screw Feeder	25	2	Filtrate Pump 1-1/2"			
8	2	Pump 5 x 4	17	1	Dryer	26	3	Moisture Trap			
9	-	24" Conveyor Belt	18	1	24" Conveyor Belt #24	27	2	Vacuum Pump			

RAY SMELTER REVERBERATORY, CONVERTER, & ANODE CASTING

REVISED 6/11/74

FLOWSHEET IX



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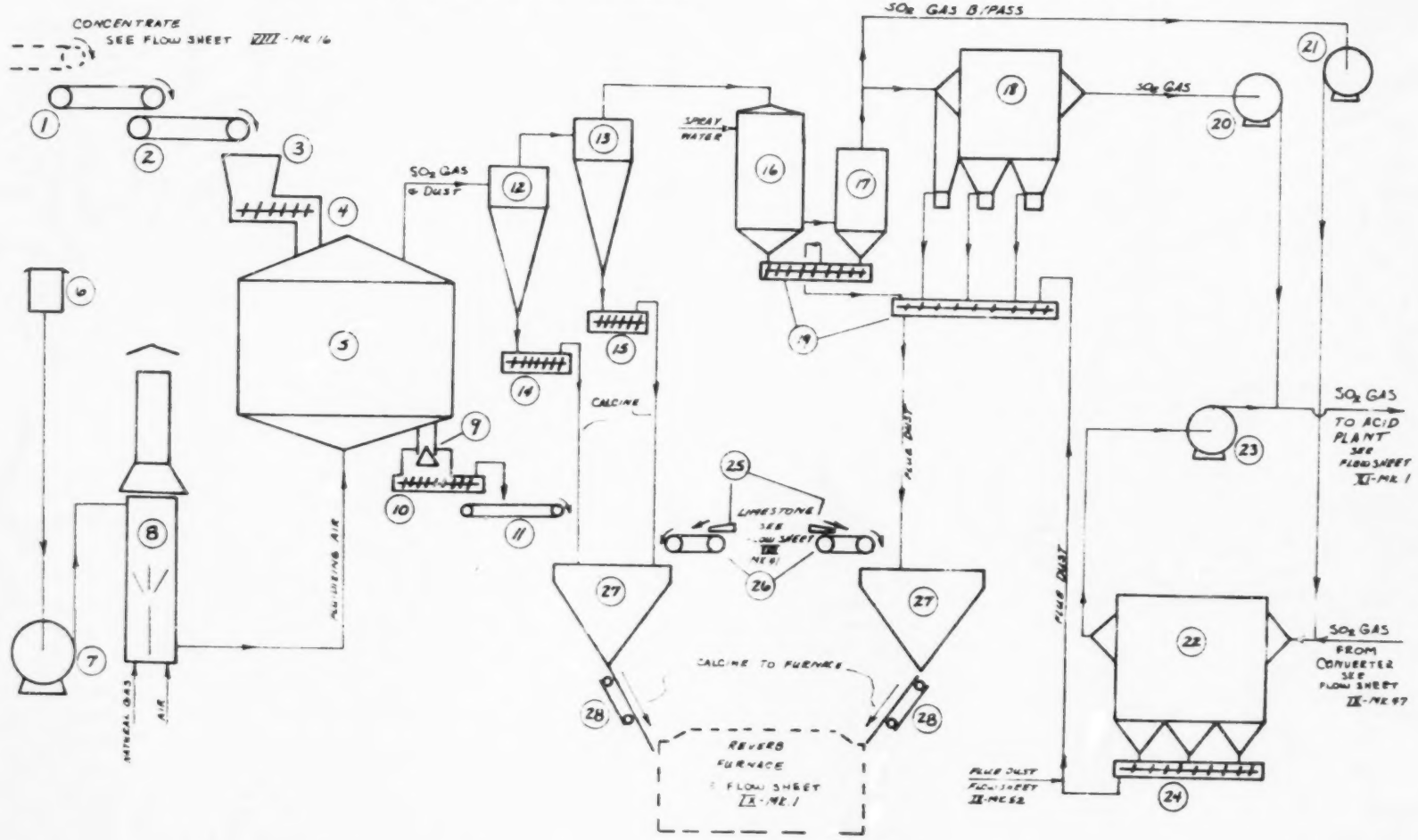
NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION
1	Waste Feed Door	21	Wasted Heat Boilers	33	Converter Gas Cooler	34		45	Railroad Box Car	1	Anode Casting Wheel
2	Reverberatory Furnace	22	Reverberatory Uptake	34	Reverberatory Boiler Flue	35	4	Fork Lift Truck	46	2	Bosh Tank
3	Burners	23	Dust Collecting Hoppers	35	Reverberatory Flue Screw Conveyor	36	1	Pump Pump	47	1	600' High Stack
4	Matte Launder	24	Fixed End Loader	36	Electrostatic Precipitator	37	3	Anode Cooling Water Pumps			
5	Slag Launder	25	Slag Fume Exhaust	37	High Velocity Flues	39	1	Anode Cooling Water Tower			
6	Matte Transfer Cars	26	Matte Fume Exhaust Fan	38	Converter ID Fan	39	2	Anode Cooling Recirculating Pumps			
7	Anode Furnace	27	Matte Fume Exhaust Fan	39	Dust Hopper	40		Propane Storage			
8	Anode Furnace	28	Converter Slag Return Launder	40	Precipitator Screw Conveyor	41		200 Cu. Ft. Ladle			
9	Reverberatory Gas Reheater	29	Slag Cu. Ft. Ladle	41	60 Ton Converter Aisle Crane	42	2	Anode Furnace			
10	Furnace Draft Fan	31	Casting Cranes	42	Casting Crane	43	2	Anode Wheel Pouring Spoon			
11	Reverberatory Air Fan	32	Converter Hood	43	Track Scale	44	1	Bosh Crane			

RAY SMELTER FLUOSOLIDS SYSTEM

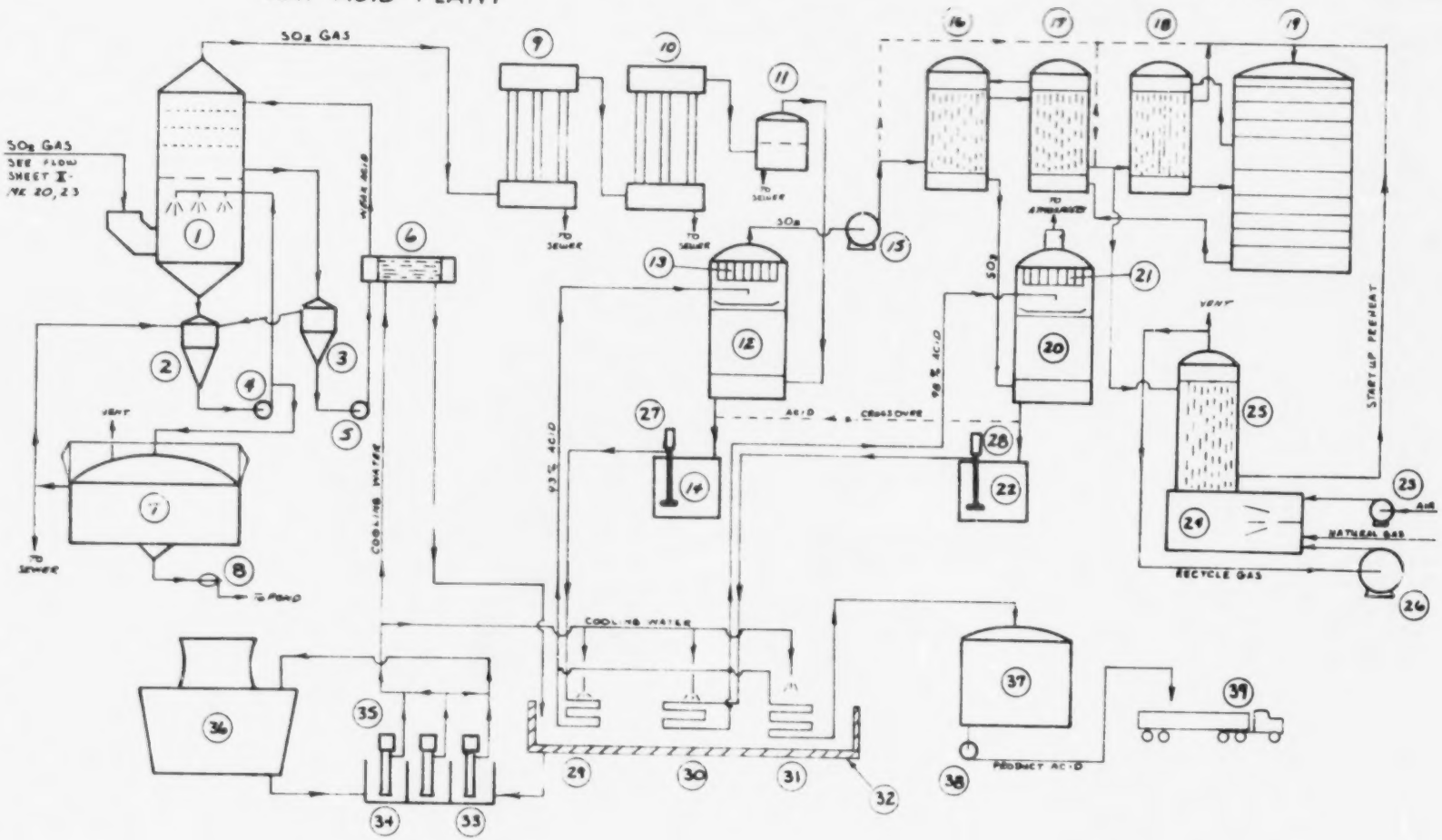
FLOW SHEET X



MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION
1	1	24" Conveyor Belt	9	1	Underflow	17	1	Gas Cooler Upleg	25	2	Vibratory Feeders
2	1	24" Conveyor Belt	10	1	Underflow Seal Screw	18	1	Calcine Electrostatic Precipitator	26	2	Belt Conveyor
3	1	Concentrate Feed Hopper	11	2	Drag Chain Conveyor	19	10	Screw Conveyors	27	2	Calcine Feed Bin
4	2	Concentrate Screw Feeder	12	4	Primary Cyclone	20	1	Reactor ID Fan	28	2	Cutoff Feeder
5	1	Fluosolids Reactor	13	4	Secondary Cyclone	21	1	Reactor ID Fan, Bypass			
6	1	Air Filter	14	2	Primary Cyclone Seal Screw	22	1	Converter Gas Electrostatic Precipitator			
7	1	Fluidizing Air Blower	15	2	Secondary Cyclone Seal Screws	23	1	Converter Gas ID Fan			
8	1	Preheater		1	Gas Cooler	24	19	Screw Conveyors			

RAY ACID PLANT

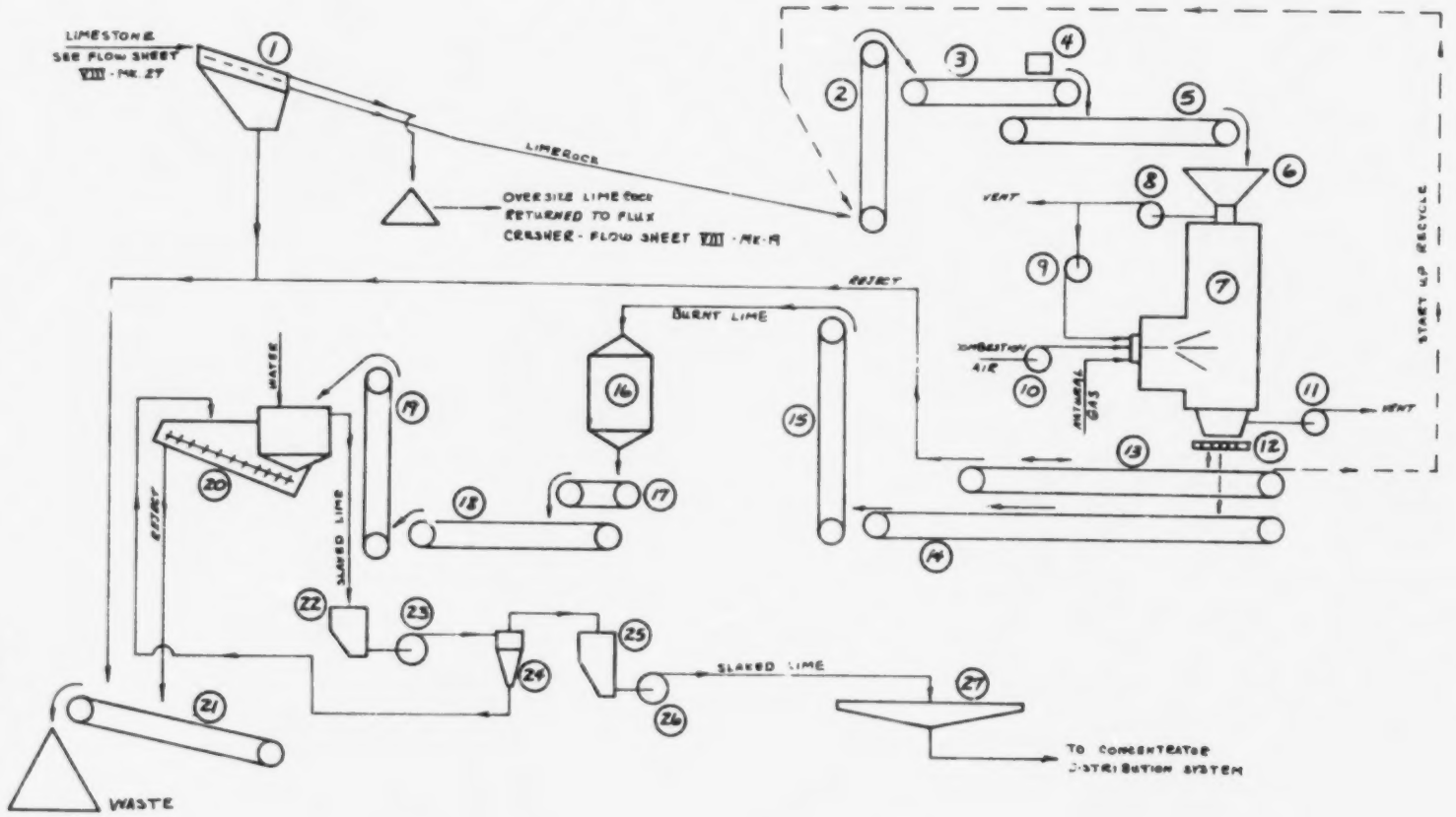
FLOW SHEET XI



MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION
1	1	Peabody Gas Scrubber	11	3	Washing Chambers	21	1	Brink Mist Eliminator	31		Product Acid Coolers
2	1	Lower Recycle Tank	12	1	Drying Tower	22	1	98% Acid Pump Tank	32	1	Acid Cooler Basin
3	1	Upper Recycle Tank	13	1	Brink Mist Eliminator	23	1	Combustion Air Fan	33	1	Hotwell Sump
4	1	Lower Recycle Pump	14	1	93% Acid Pump Tank	24	1	Combustion Chamber	34	1	Coldwell Sump
5	2	Upper Recycle Pump	15	2	SO2 Blower	25	1	Preheat Heat Exchanger	35	5	Circulating Water Pumps
6	4	Cascade Heat Exchangers	16	1	No. 1 Cold Heat Exchanger	26	1	Recycle Fan	36	1	Cooling Tower
7	1	98% Acid Storage - 50' D	17	1	No. 2 Cold Heat Exchanger	27	1	93% Acid Circulating Pump	37	4	5000 Ton Storage Tank
8	2	Underflow Pumps, Sludge	18	1	Hot Heat Exchanger	28	2	98% Acid Circulating Pump	38	3	Acid Loading Pumps
9	3	Mist Precipitator	19	1	Converter Catalyst Chamber	29		Drying Tower Acid Coolers	39		Truck Wellage To Bay
10	3	Mist Precipitator	20	1	Absorbing Tower	30		Absorbing Tower Acid Coolers			

RAY SMELTER LIME PLANT

FLOW SHEET XII



MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION	MK	NO	DESCRIPTION
1	1	3' x 6' Double Deck Screen	9	5	Circulating Blower	17	2	24" Feedweight Conveyors 8' - 7" lg.	25	1	Sump
2	1	Bucket Elevator	10	5	Combustion Air Blower	18	1	24" Belt Conveyor 54' - 0 - 3/4" lg.	26	2	Lime Pumps
3	1	24" Belt Conveyor 44' - 6" lg.	11	5	Diverting Air Blower	19	1	Bucket Elevator	27	1	75' Dia. Milk of Lime Storage Tank
4	1	Weightometer	12	5	Discharge Rakes	20	1	16' - 0" Dia. Slaker			(At Concentrator Area)
5	1	24" Shuttle Belt Conveyor 48' - 0" lg.	13	1	14' Reversible Belt Conveyor 155' - 3"	21	1	18" Belt Conveyor 184' - 10" lg.			
6	5	Storage Bins, 200 Tons Each	14	1	14" Belt Conveyor 116' - 9" lg.	22	1	Pump Sump			
7	5	Vertical Kilns, Ellerman Type	15	1	Bucket Elevator	23	1	Lime Pump			
8	5	Exhaust Blower	16	2	Storage Bins, 250 Tons Each	24	1	Cyclone			